BBC

PARLIAMENT'S PLAN TO PRESERVE DARK SKIES
MPs' proposals to tackle the growth of light pollution

#193 JUNE 2021

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

GET READY FOR THE ECLIPSE!

Watch a spectacular partial solar eclipse across the UK this month

A FORECAST FOR THE SUN

The challenge of predicting when solar activity will peak

WIDE-FIELD WONDERS

Track down the treasures of Cygnus with binoculars

PICTURE THE PLANETS

Capture the worlds of the Solar System with our guide

REFINING HUBBLE

The imagers enhancing space mission photos

DAWN OF THE UNIVERSE

20 years since WMAP viewed the early cosmos

MYSTERY MARS CLOUD

Red Planet's 1,800km weather feature revealed

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Welcome

Get ready to enjoy a view of the partial solar eclipse!

The excitement was building at *Sky at Night Magazine* as we put this issue together, in anticipation of the partial solar eclipse that's soon to be visible across the UK. On the morning of Thursday 10 June, the Moon will obscure a sizeable chunk of the Sun's disc for viewers on this part of the planet – we won't see a greater solar eclipse until 2025 – making it appear as a dramatic crescent shape. Get ready to witness the spectacle with our observing guide on **page 46**, imaging guides on **pages 73 and 76**, and ideas for simple ways to view without the Sun's bright glare damaging your eyesight on **page 72**.

We stay with the Sun elsewhere in this issue too, with a look behind the scenes at how astronomers forecast the level of solar activity. This manifests itself as a pattern of sunspots on the visible surface of our nearest star and has a direct impact on our tech-driven lives today, in the form of an increase in flares and other space weather hitting Earth around the time of peak activity. The Sun having recently passed through a lull in activity, on **page 28** we look at the challenges solar scientists face in predicting when Solar Cycle 25 will reach peak strength over the coming decade.

We're also reporting on a cross-parliamentary plan to strengthen the law around dark skies protection on **page 34**, remembering the WMAP mission on its 20th anniversary with a look at the groundbreaking detail of the early Universe that it provided on **page 36**, and hearing how the human genetic code could be adapted so that we survive better in space on **page 98**.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 17 June.

HOW TO CONTACT US

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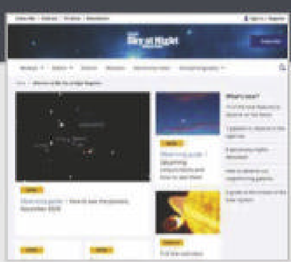
Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18



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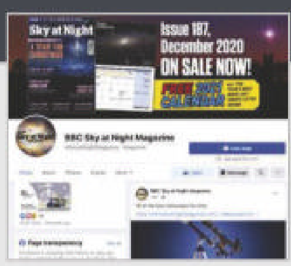

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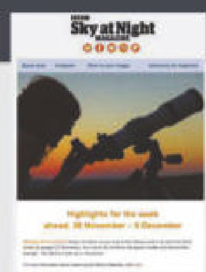

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The best targets to observe each week, delivered to your inbox. Visit **bit.ly/skynewsletter**

Find out more at: www.skyatnightmagazine.com

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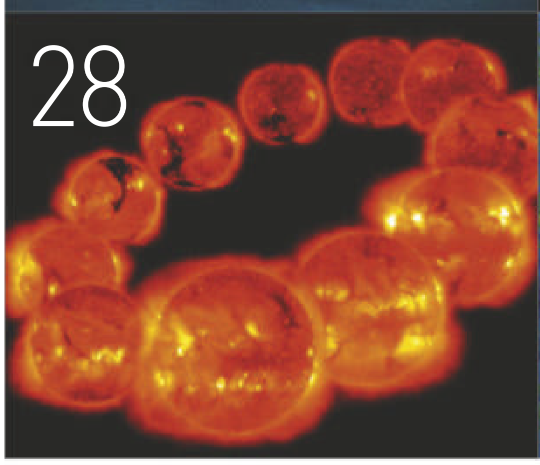
C = on the cover

COVER MAIN IMAGE: PIALHOVIK/ISTOCK/GETTY IMAGES. THIS PAGE: PETE LAWRENCE X 2, NASA/ESA AND M. LIVIO AND THE HUBBLE 20TH ANNIVERSARY TEAM (STSCI)/JUDY SCHMIDT, NASA/WMAP SCIENCE TEAM, PIXELPARTICLE/ISTOCK/GETTY IMAGES, JAXA/NAOJ/NASA/SAO, @THESHED_PHOTOSTUDIO, BBC, © BORIS BREUER

New to astronomy?

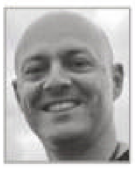
To get started, check out our guides and glossary at
www.skyatnightmagazine.com/astronomy-for-beginners



This month's contributors

Jamie Carter

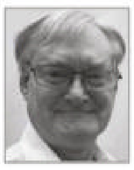
Astronomy journalist



"Everyone wants to see more stars, and light pollution is easy to fix. All the UK's dark skies movement needs now is the law on its side." **Jamie outlines what Westminster's APPG for Dark Skies wants to legislate for, page 34**

Paul Money

Reviews editor



"Although annular for the Arctic region, we still get to see a partial solar eclipse from the UK on 10 June so, weather-permitting, it's best to be prepared in advance!" **Paul gets ready for the partial solar eclipse, page 72**

Stephanie Yardley

Space weather expert

"I am excited to see what the Sun has in store for us during Solar Cycle 25. Recently, solar activity has started to increase and so it looks like the Sun may have woken up!" **Stephanie looks at how solar activity is forecast, page 28**

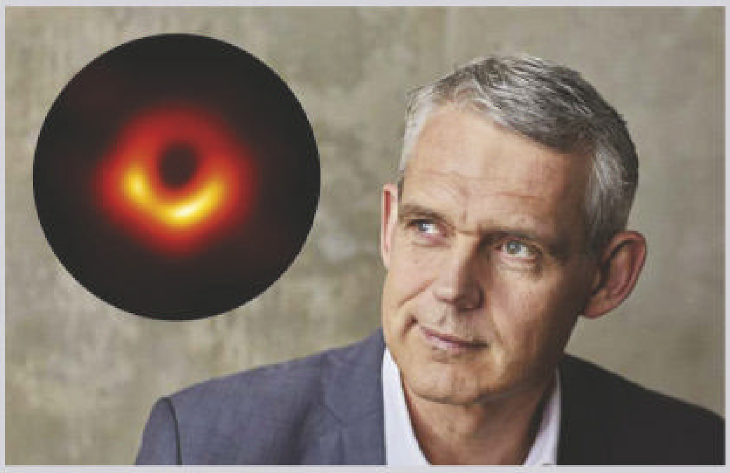
Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/EENHE5U/** to access this month's selection of exclusive Bonus Content

JUNE HIGHLIGHTS

Interview: how to capture a black hole

Astronomer Heino Falcke reveals how an Earth-sized telescope photographed the black hole in galaxy M87.



Watch *The Sky at Night: Mars and Meteorites*

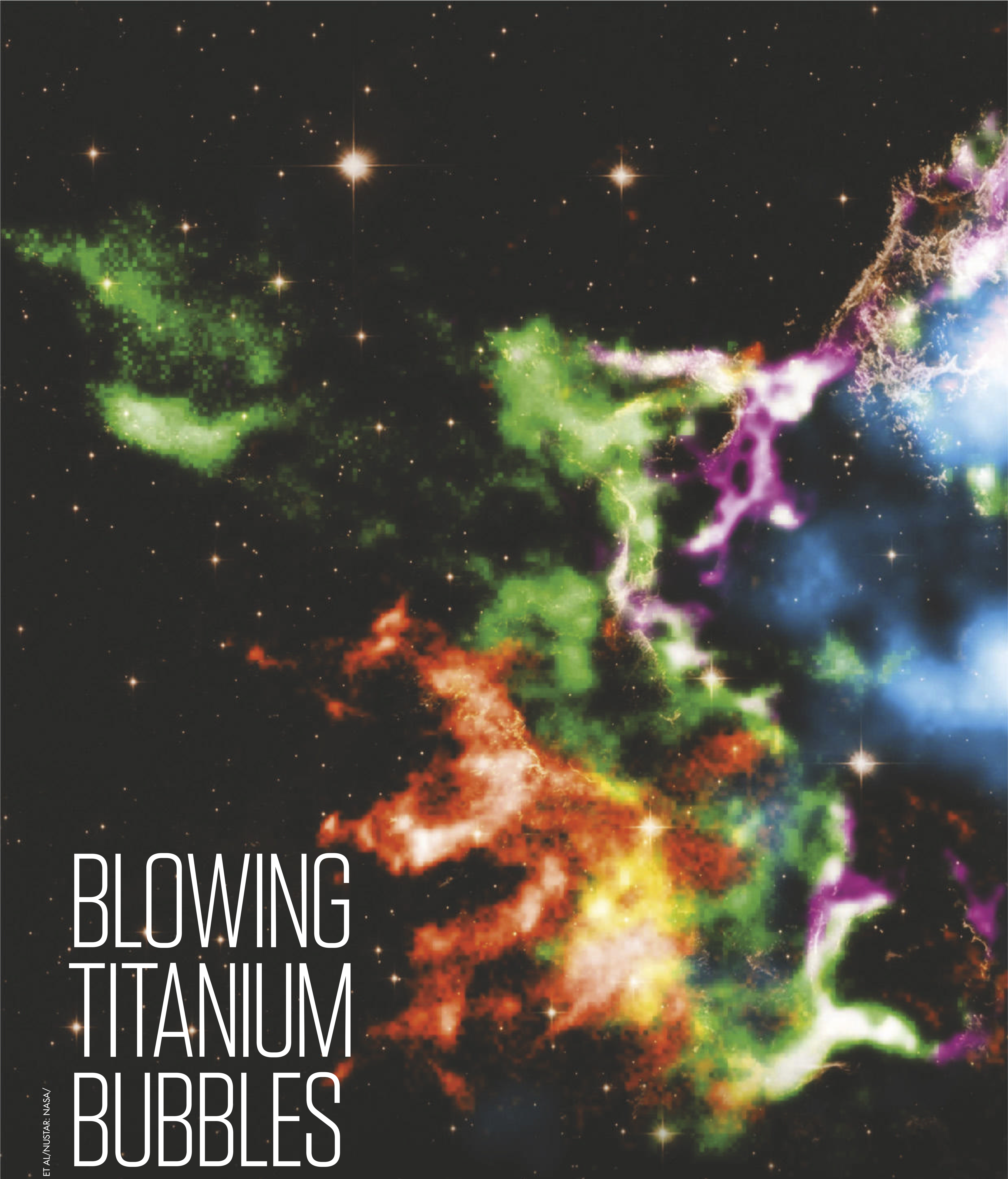
Chris and Maggie get the latest on the new probes exploring Mars and report on the discovery of the Winchcombe meteorite.

Download exclusive observing resources

Access planet and solar observing forms, and software to guide your telescope through this month's deep-sky tour.

The Virtual Planetarium

Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.



BLOWING TITANIUM BUBBLES

Traces of the stable element provide a clue as to how some massive old stars go supernova

CHANDRA X-RAY OBSERVATORY/NUSTAR/HUBBLE SPACE TELESCOPE, 21 APRIL 2021

CHANDRA: NASA/CXC/RIKEN/T. SATO ET AL/NUSTAR: NASA/NUSTAR; HUBBLE: NASA/STSCI

Reminiscent of a child's painting, this kaleidoscopic creation is supernova remnant Cassiopeia A (Cas A), revealed by new research to be blasting out unusual titanium bubbles.

Finding 'stable' titanium for the very first time – among other elements including iron (orange), oxygen (purple), silicon/magnesium (green) and the much more common unstable titanium (light blue) – adds strength to the theory that neutrinos (very low mass subatomic particles) are what drive the shockwaves necessary for massive fuel-depleted stars to explode as supernovae.

◁ ET drone flown

MARS PERSEVERANCE, 19 APRIL 2021

Mars Perseverance's Navcam acquired these images of the Ingenuity helicopter making history: the first (human-made) powered, controlled flight on another world. The drone-like craft climbed to a height of 3m and hovered for 30 seconds before touching back down, a flight of 39.1 seconds. Within the week it had completed two longer successful flights.

MORE **ONLINE**
A gallery of these and more stunning space images

▽ Squeaky clean comet

VERY LARGE TELESCOPE, DECEMBER 2019

New research suggests 2I/Borisov may be one of the most pristine comets ever observed. Only the second interstellar traveller seen in our Solar System (after 'Oumuamua in 2017), and the first confirmed interstellar comet, it was discovered by amateur astronomer Gennady Borisov in August 2019. Polarimetry, the measurement of the angular rotation of a body on polarised light, now reveals that it contains unaltered traces of the gas and dust in which it first formed – evidence that it never passed close to any other stars before its flying visit to our Solar System. The colourful streaks are background stars in this multi-wavelength composite image.

◁ Bye bye, Bennu

OSIRIS-REX, 20 APRIL 2021

OSIRIS-REx has taken one final look at asteroid Bennu before heading home to give up its secrets. The craft imaged the churned-up landing site – marked with an X in the image – where it successfully gathered 60g of sample materials in its Touch-and-Go, or TAG, manoeuvre last October. A large boulder is circled, showing it has been flung about 12m from the agitated landing site.

After this final flyby, just 3.7km from Bennu's surface, OSIRIS-REx begins its two-year return cruise back to Earth, where the jettisoned sample capsule will parachute down to Utah, USA in September 2023.

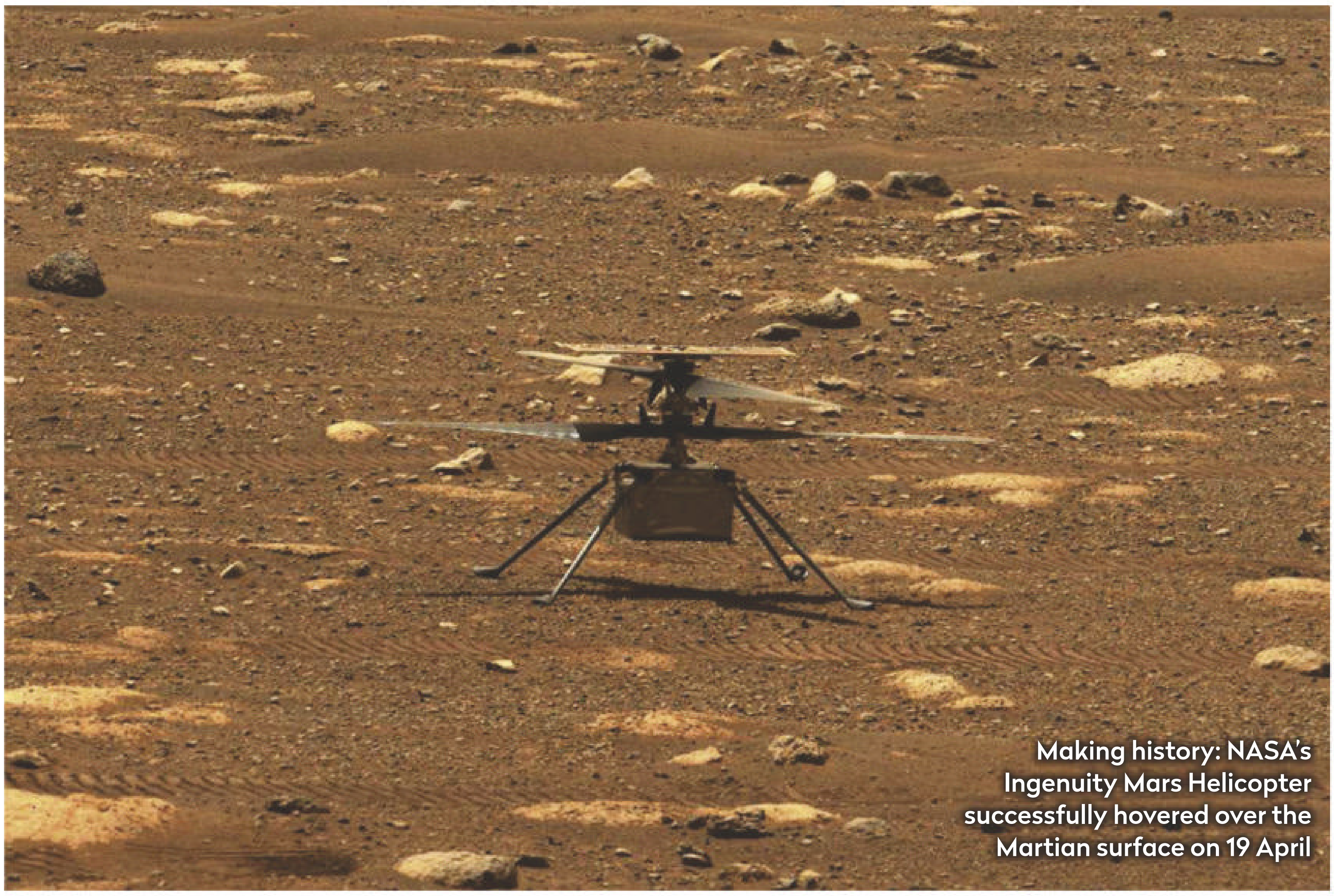
Sparkly spin cycle

HUBBLE SPACE TELESCOPE, 26 APRIL 2021

The aftermath of a star's collision with its binary companion, this is the Necklace Nebula, or PN G054.2-03.4. The clash left the larger dying star spinning so fast that its gaseous envelope expanded into space, creating this bejewelled circle of debris. The 'gems' are dense, bright knots of gas, glowing with the ultraviolet light they absorb from the two stars.

NASA/JPL-CALTECH/ASU, ESO/O. HAINAUT, NASA/GODDARD/ UNIVERSITY OF ARIZONA, ESA/HUBBLE & NASA/K. NOLL

BULLETIN



Making history: NASA's Ingenuity Mars Helicopter successfully hovered over the Martian surface on 19 April

NASA/JPL-CALTECH/ASU, NOIRLAB/NSF/AURA/J. DA SILVA, REIDAR HAHN/FERMILAB

Perseverance tests technology on Mars for future missions

A historic helicopter flight and successful oxygen extraction lead the way

It's been a busy April for NASA's Perseverance rover, as it spent the month trialling two pioneering technology demonstrations – a drone-like helicopter and a device to extract oxygen from the atmosphere. Both experiments could be used on future robotic and human missions to the Red Planet.

On 19 April, the Ingenuity Mars Helicopter – a 1.8kg rotocopter – made history with the first powered flight from the surface of another planet. This initial flight saw Ingenuity rise up to a height of 3m, hover for 30 seconds and then land.

The 20cm-long robot chopper performed a total of five flights of increasing complexity. As of writing, the third of these flights saw the spacecraft travel laterally for 50m before returning to its starting point.

"What the Ingenuity team has done is given us the third dimension," says Michael Watkins, director of the Jet Propulsion Laboratory. "They've freed us from the surface now, forever, in planetary exploration."

In future, similar craft could carry scientific equipment up to 4kg in mass which it could then fly to areas where the terrain is too rugged or dangerous for Martian rovers to reach.

Meanwhile, on the main rover itself the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE) successfully extracted oxygen from the planet's atmosphere by breaking apart carbon dioxide on 20 April. Though MOXIE only produced 5.37g of oxygen, scaled up versions of the technology could provide much more.

"Oxygen isn't just the stuff we breathe," says Jim Reuter, from NASA's Science Technology Mission Directorate. "Rocket propellant depends on oxygen, and future explorers will depend on producing propellant on Mars to travel home."

http://mars.nasa.gov

Comment

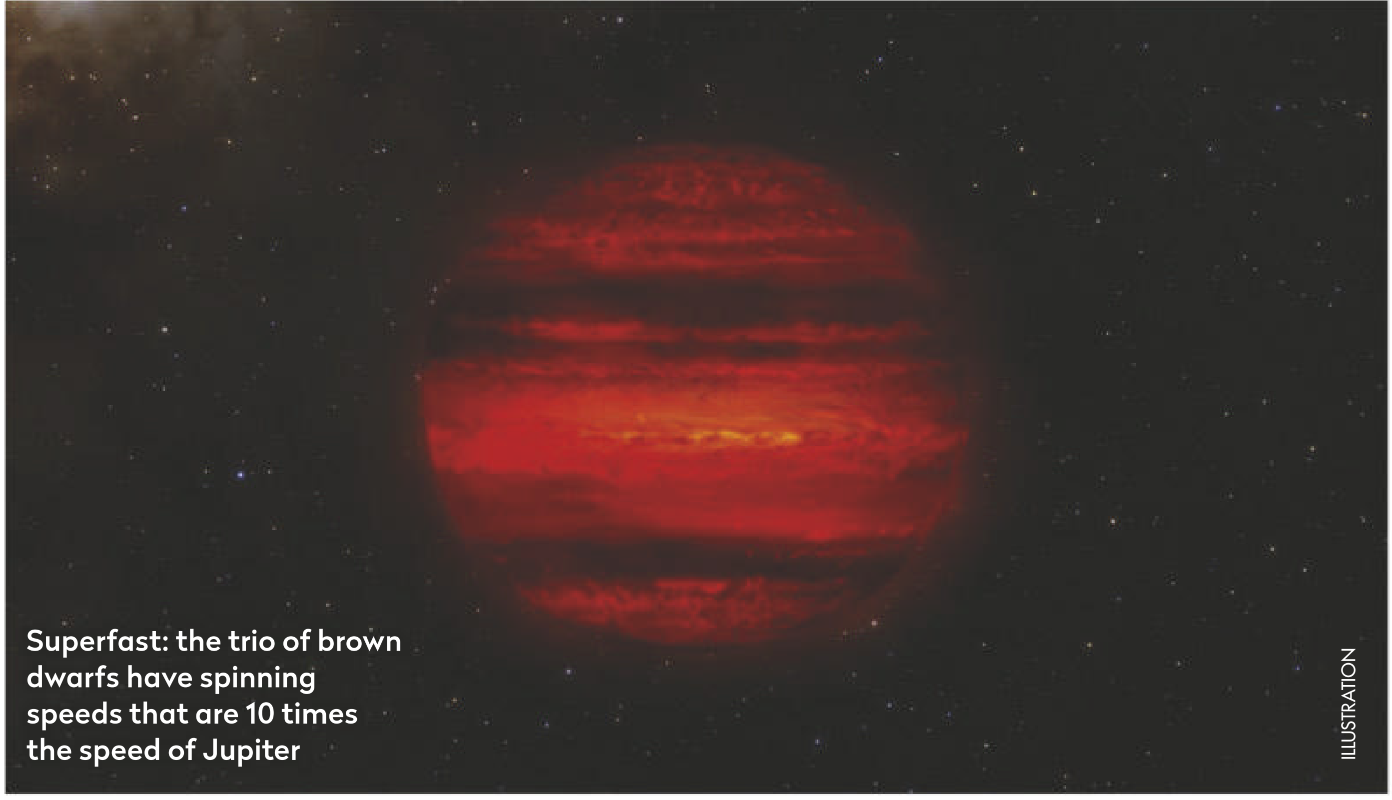
by Chris Lintott

The last time two robots operated in tandem on the Martian surface was 1997 when the Sojourner rover explored the area around the Pathfinder lander.

Like Sojourner, Ingenuity is a demonstration mission, and it's easy to imagine its successors scouting ahead of future rovers or conducting science missions, hopping from site to site, as the Dragonfly mission to Titan hopes to do in 2036.

But NASA's plans for the next decade call for a string of missions to retrieve samples of rocks stowed by Perseverance, not for helicopter-powered exploring. Without a dramatic rethink, and more money, it may be a long while before anything but Ingenuity flies in the thin Martian air.

Chris Lintott co-presents *The Sky at Night*



Superfast: the trio of brown dwarfs have spinning speeds that are 10 times the speed of Jupiter

Brown dwarfs in a spin

Stars found rotating at record speeds

A trio of speedy brown dwarfs have set a new record for how fast these failed stars can spin. It's thought the trio are whizzing round at the limit of how fast they can go and remain intact.

A team of astronomers used the Spitzer Space Telescope to track down the fastest spinning brown dwarfs they could find, locating three stars which spun at 350,000km/h.

"Despite extensive searches, by our own team and others, no brown dwarfs have been found to rotate any faster," says Megan Tannock from Western University in Canada, who led the study. "Faster spins may lead to a brown dwarf tearing itself apart."

When something spins, its material gets thrown outwards, acting against the gravity that holds it together. It's thought this could be a speed limit, determining exactly how fast a brown dwarf can spin before it flies apart.

www.spitzer.caltech.edu

Cosmic rays poke holes in particle physics

Wilson Hall at Fermilab's 6,800 acre site near Chicago, where the muon g-2 experiment is also located

Physicists are returning to the drawing board after the first results from a new experiment revealed flaws in the Standard Model – a set of equations which are our best theory of how sub-atomic particles and forces interact.

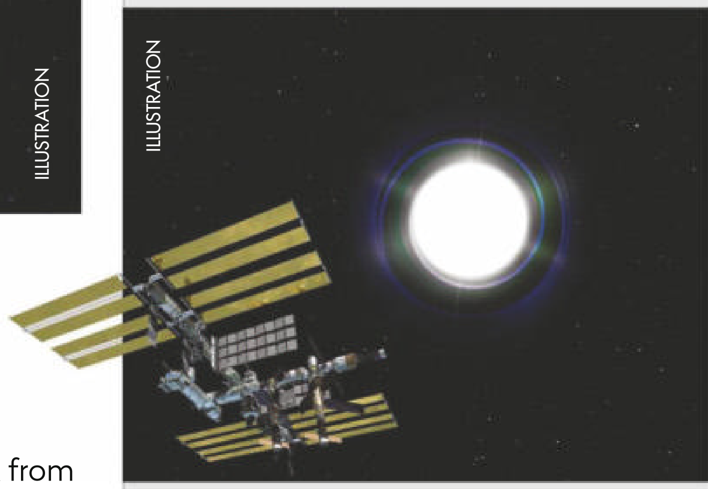
The Muon g-2 experiment at Fermilab in the US looked at muons – particles similar to an electron but 200 times more massive – created by cosmic rays hitting Earth's atmosphere. They measured how much the muons wobbled as they passed through the detector.

"This quantity we measure reflects the interactions of the muon with everything else in the Universe. But when the theorists calculate the same quantity, using all of the known forces and particles in the Standard Model, we don't get the same answer," says Renee Fatemi, from the University of Kentucky, who worked on the study "This is evidence that the muon is sensitive to something that is not in our best theory."

The discrepancy suggests an unknown particle or force is at work, which theorists will now try to work into a new model.

http://fnal.gov

NEWS IN BRIEF



Pushing the limits

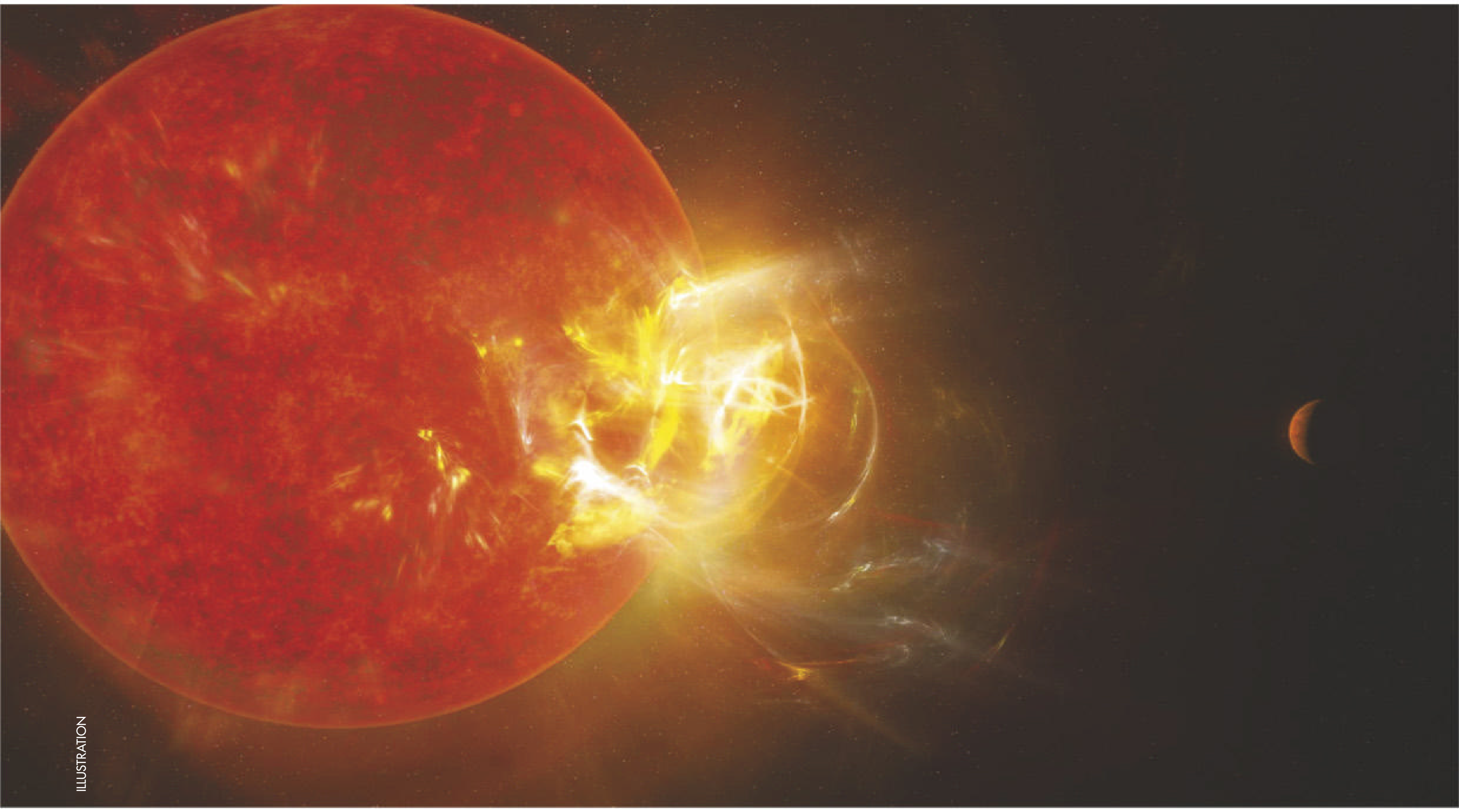
Astronomers recently used a special telescope on board the International Space Station to observe the largest neutron star we know of in unprecedented detail. They plan to use their findings to work out how large these stars can grow before they collapse and become black holes.

Interstellar probe

A new mission proposal for the first ever dedicated interstellar probe is being submitted to NASA. If funded, the spacecraft would travel out of the Solar System to explore beyond the heliosphere – the bubble created by the Sun's magnetic field – eventually travelling 1,000 times the Earth-Sun distance.

Far flung giant

Astronomers are scratching their heads trying to work out why the giant planet YSES 2b, which was discovered in a recent survey of young stars, formed so far away from its planet. It's six times heavier than Jupiter but 20 times further out – much more distant than our current theories of planet formation say it should be.



▲ **The violent mega-flare from Proxima Centauri, examined by scientists using nine telescopes, made the red dwarf 14,000 times brighter**

Proxima Centauri's ferocious flare

Intense outburst on the Sun's nearest star is bad news for its orbiting planet

One of the most powerful flares ever seen has erupted from our neighbouring star, Proxima Centauri. A new paper revealed the flare was 100 times more powerful than anything ever seen ejecting from our own Sun and would have ravaged the atmosphere of the star's planet.

The flare was first observed coming from the red dwarf star on 1 May 2019. It lasted just seven seconds. Though it didn't release a huge amount of visible light, it created massive amounts of ultraviolet, radio and millimetre radiation.

"The star went from normal to 14,000 times brighter when seen in ultraviolet wavelengths over the span of a few seconds," says Meredith MacGregor from the University of Colorado, Boulder, who headed up the study. "In the past we didn't know that stars could flare in the millimetre range, so this is the first time we have gone looking for millimetre flares."

To get the full picture of the flare across the electromagnetic spectrum, MacGregor's team spent several months observing Proxima Centauri for a total of 40 hours, using nine different telescopes including the Hubble Space Telescope, the Atacama Large Millimetre Array and NASA's Transiting Exoplanet Survey.

"It's the first time we've ever had this kind of multi-wavelength coverage of a stellar flare," says MacGregor. "Usually you're lucky if you can get two instruments."

During these observations, the astronomers observed many other, smaller flares being ejected from the star. While this was good news for the astronomers trying to understand the physics behind the mega-flare on 1 May, it was less good news for the star's planet, Proxima Centauri b. The planet lies in the star's habitable zone, meaning it has the right temperature range for liquid water to persist on the surface and could potentially host life as we know it. Unfortunately, the constant bombardment by radiation from these flares would strip away the planet's atmosphere, making it much less likely life could survive there.

"If there was life on the planet nearest to Proxima Centauri, it would have to look very different than anything on Earth," says MacGregor. "A human being on this planet would have a bad time."
www.colorado.edu

S. DAGNELLO/NRAO/AUI/NSF, NASA

Apollo 11 astronaut Michael Collins dies, aged 90

Michael Collins, the astronaut who piloted the Apollo 11 Command Module in lunar orbit while Neil Armstrong and Buzz Aldrin descended to the surface, passed away on 29 April.

Collins was born on 31 October 1930 into a distinguished military family, but ultimately it was the rapidly evolving field of aeronautics which drew his attention and he joined the US Air Force in 1952. In between his deployments at bases around the world, Collins met and married Patricia, and they had three children.

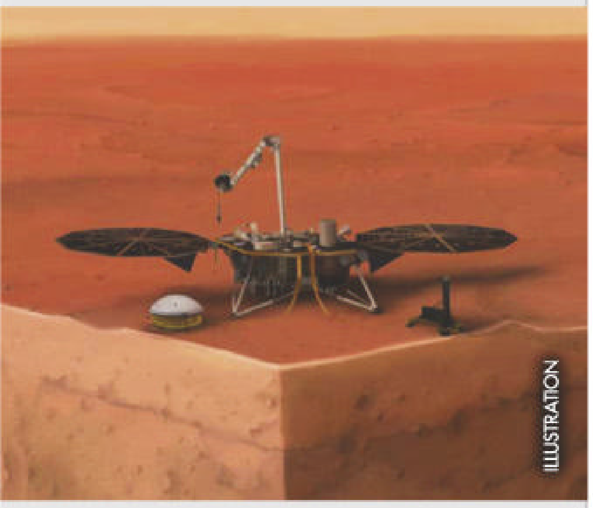
In 1962, while working at the Edwards Air Force Base as a test pilot, Collins was inspired by John Glenn's orbital flight and joined NASA's third class of astronauts. After his maiden spaceflight on Gemini 10, where he performed two spacewalks, he was assigned to Apollo 11 as the Command Module pilot. During this flight, he remained alone in the orbiting spacecraft. When his spacecraft passed through the shadow of the Moon, his radio went out of range and for a few minutes he was completely out of contact – becoming the loneliest human in history.

Collins left NASA after Apollo 11, going on to serve in the State Department and as Director of the Smithsonian Air and Space Museum, overseeing the construction and opening of the new building on the National Mall in Washington DC, in July 1976. He found time to write three books, including his bestselling autobiography, *Carrying the Fire*, which is acclaimed as one of the most inspirational first-hand accounts of space travel.

"I have been places and done things you simply would not believe," he says in the book. "...I have dangled from a cord a hundred miles up; I have seen the Earth eclipsed by the Moon and enjoyed it. I have seen the Sun's true light, unfiltered by any planet's atmosphere. I have seen the ultimate black of infinity in a stillness undisturbed by any living thing."

▲ **Apollo 11 Command Module pilot Michael Collins travelled around the Moon's dark side while Armstrong and Aldrin were on the surface**

NEWS IN BRIEF



An InSightful year

NASA's InSight probe spent its first full Martian year on the surface of the Red Planet. The station's seismometer has detected over 500 marsquakes in that time, though it has failed to deploy a probe which would have measured how heat flows out of the planet.

Small galaxies, big impact

Diminutive galaxies may have had a huge role in the early evolution of the Universe. Hydrogen clouds in large galaxies soaked up high-energy light but a study has shown that smaller galaxies were able to remove the clouds. The light could then escape and ionise the Universe by knocking electrons off the gas found between stars and galaxies.

Lunar lander for SpaceX

NASA has selected spaceflight company SpaceX to build the new crewed lunar lander for the upcoming Artemis mission. The lander will be based on the company's Starship vehicle, which they plan on refuelling in low-Earth orbit before travelling to the Moon.

IPGP/NICOLAS SARTER, EERIK/ISTOCK/GETTY IMAGES, CMSA, NASA/CHRIS GUNN

BULLETIN

Lockdown lowers light pollution

In a survey, stargazers could see more stars than in previous years


Dark nights: UK stargazers have counted more stars on view during lockdown

Lockdown caused a 10 per cent drop in light pollution, according to the annual Star Count conducted by CPRE, the countryside charity, between 6 and 14 February 2021. Nearly 8,000 stargazers across the UK counted how many stars they could see in the constellation of Orion as part of the organisation's yearly event to track the darkness of British skies.

The survey found that only 51 per cent of people reported seeing 'severely light polluted skies' where only 10 or fewer stars were visible, down from 61 per cent last year. Just as positive was the fact that more people than ever reported seeing 30 or more stars, indicating truly dark skies – the highest figure since 2013.

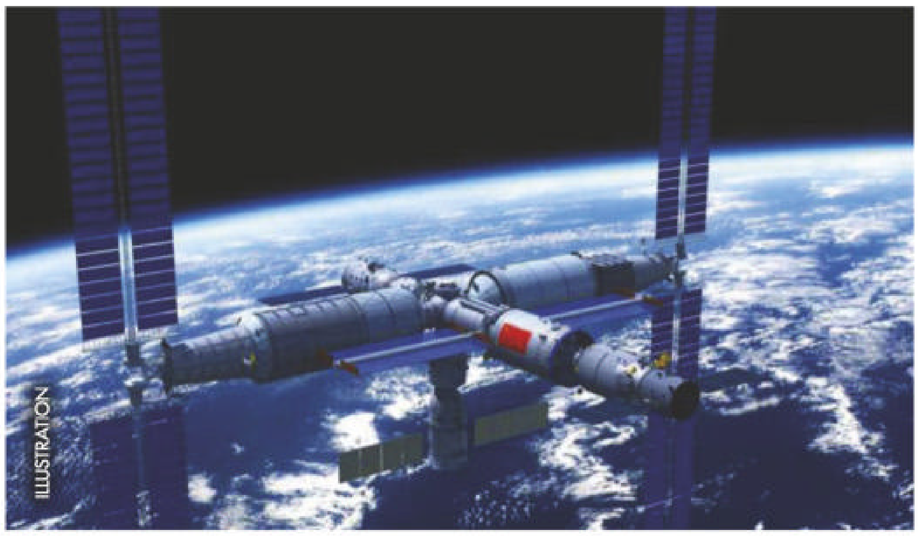
"Dark skies are crucial for our health and for that of wildlife," says Crispin Truman, chief executive of CPRE.

"Lockdown and the coronavirus have reminded us about how good for us the countryside can be."

www.cpre.org.uk

China and Russia advance space stations

China has begun the construction of its first permanent orbital space station, having launched the core module, Tianhe, on 28 April. Over the next two years, the Chinese space agency has scheduled a further 10 crewed and uncrewed launches to continue construction of the three-module outpost. This is the culmination of the Tiangong project the Chinese National Space Agency has been working on for decades, having already successfully tested two temporary stations in low-Earth orbit.



▲ The construction of China's Tiangong space station begins, nearly 30 years after the project was first approved

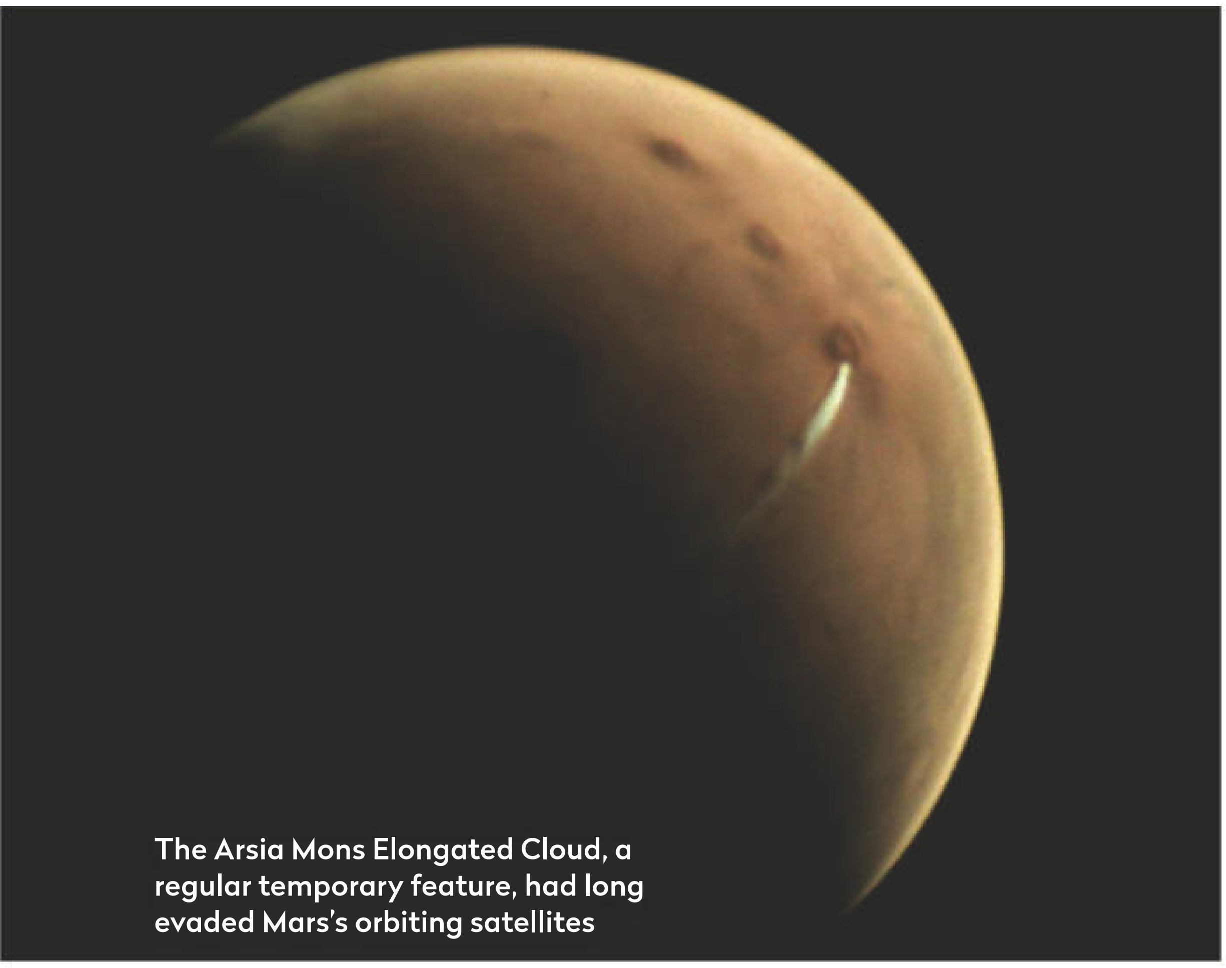
Meanwhile, Russia announced plans to collaborate with China on a lunar station, and that they may build their own low-Earth orbit outpost, as an increasing number of technical problems with the ageing International Space Station means they could withdraw from the ISS by as soon as 2025. As the station relies on Russian-made components, this could put the future of the ISS in jeopardy, but NASA's acting administrator Steve Jurczyk was keen to point out that they still had a "strong relationship with Roscosmos and Russia on the ISS."

www.cnsa.gov.cn/english

JWST packs up for its trip

NASA's James Webb Space Telescope has folded up its sunshield as the agency prepares it – finally – for launch.

Once in orbit, the sunshield will unfold to protect the highly sensitive infrared telescope from the Sun's heat. Made from five layers of delicate Kapton – the foil-like material often used on spacecraft to reflect sunlight – the construction and folding of the sunshield has been one of the telescope's most complex procedures. Problems with its development and construction have been one of several issues responsible for delaying the spacecraft's launch for several years. Fortunately, it now looks like the JWST is on track, and will be ready for launch in October 2021.



The Arsia Mons Elongated Cloud, a regular temporary feature, had long evaded Mars's orbiting satellites

Clouds over a Martian mountain

The 1,800km-long weather feature holds a key lesson for research

The Cloud Appreciation Society was founded in 2005 by British author, Gavin Pretor-Pinney, and now has over 50,000 members around the world. From a wispy cirrus on a summer day to a roiling cumulonimbus threatening a violent storm, the society revels in all meteorological phenomena in Earth's skies. But many of the other planets in the Solar System have atmospheres, and their clouds bring just as much joy to the scientists studying them.

The cloud this particular paper focuses on is one found on Mars. Jorge Hernández-Bernal and his team are reporting on a previously unnoticed, extremely long cloud that forms downwind of the Arsia Mons volcano. This 'Arsia Mons Elongated Cloud' (AMEC) appears to develop every morning during the spring and summer seasons. Before dawn, a circular head of cloud, around 125km across, emerges over the western flank of the mountain, which then after sunrise extends rapidly westwards with the prevailing winds – moving at over 600km/h. Eventually this thin tail of cloud reaches almost 1,800km, wrapped around the planet. By midday the air has warmed enough that the entire stretch of cloud evaporates and disappears. Next morning, the cycle repeats again until the end of summer. The cloud stands out because the Arsia Mons volcano seems to be the only spot on Mars where water ice clouds form regularly in this season.

The team first spotted the curious cloud in 2018, and then – by checking back through archived imagery from a handful of different missions – realised it had been observed by orbiting spacecraft for years but no one had noticed it in the photographs. What they think is happening is that relatively moist air is forced to ascend in updrafts driven by wind blowing along the mountain slopes, until water ice crystals form in the very low temperatures and then high-altitude winds blow them into a long streak.

Evading detection

The reason this extremely long cloud had gone previously unnoticed was a problem of timing. Most orbiter probes sent to Mars have operated in a 'Sun synchronous orbit' – a polar orbit aligned such that the satellite passes over each point on the surface at the same time of day. This is useful for imaging because the illumination angle on surface features is always the same. For example, the Mars Global Surveyor, Mars Odyssey and Mars Reconnaissance Orbiter all had orbits aligned to pass over points with afternoon views – by which time the AMEC had already disappeared. Mars Express was the only mission in a non-Sun-synchronous orbit, until 2014 with the arrival of Mars Atmosphere and Volatile Evolution (MAVEN) and then later the ExoMars Trace Gas Orbiter (TGO).

> "The Arsia Mons Elongated Cloud (ARMC) appears to develop every morning during the spring and summer seasons"

The AMEC has been there all along, but we were just passing overhead too late in the day and missed it. This underscores the important point that sometimes in order to make a discovery it's not just crucial to be looking at the right place, but also at the right time.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *An Extremely Elongated Cloud over Arsia Mons Volcano on Mars* by J Hernández-Bernal et al.
Read it online at: https://arxiv.org/abs/2103.03919

ESA/GCP/UPV/EHU BILBAO, NASA/JPL-CALTECH

Trios of stars consume each other in parasitic dance

Expanding red giants could swamp their companions, only for the smaller stars to re-emerge later

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

Coming up with ever more unusual stellar and planetary systems used to be the job of science fiction, but it's becoming increasingly clear that nature is more than capable of producing almost anything we can dream up. All sorts of unusual systems once thought to be firmly in the realm of theory have ended up revealing themselves as part of our great galactic story.

The same will likely be true for the unusual triple system considered by Noam Soker and Ealeal Bear in this month's paper. Being a triple is in itself not too unusual; the majority of stars live in multiple systems, and perhaps five per cent of those are in triple systems. Most of these systems have two stars on a tight orbit around each other, and then a third on a loose, outer orbit around their common centre of mass.

In the systems studied by Soker and Bear, the most massive star is required to be one of the central ones, with the next massive being on the outermost orbit. All three are initially main sequence stars like the Sun, with masses no more than eight times that of our own star. As more massive stars burn through their fuel quickest, it will be the most massive star in the innermost pair that will deplete its hydrogen first, swelling to be a red giant.

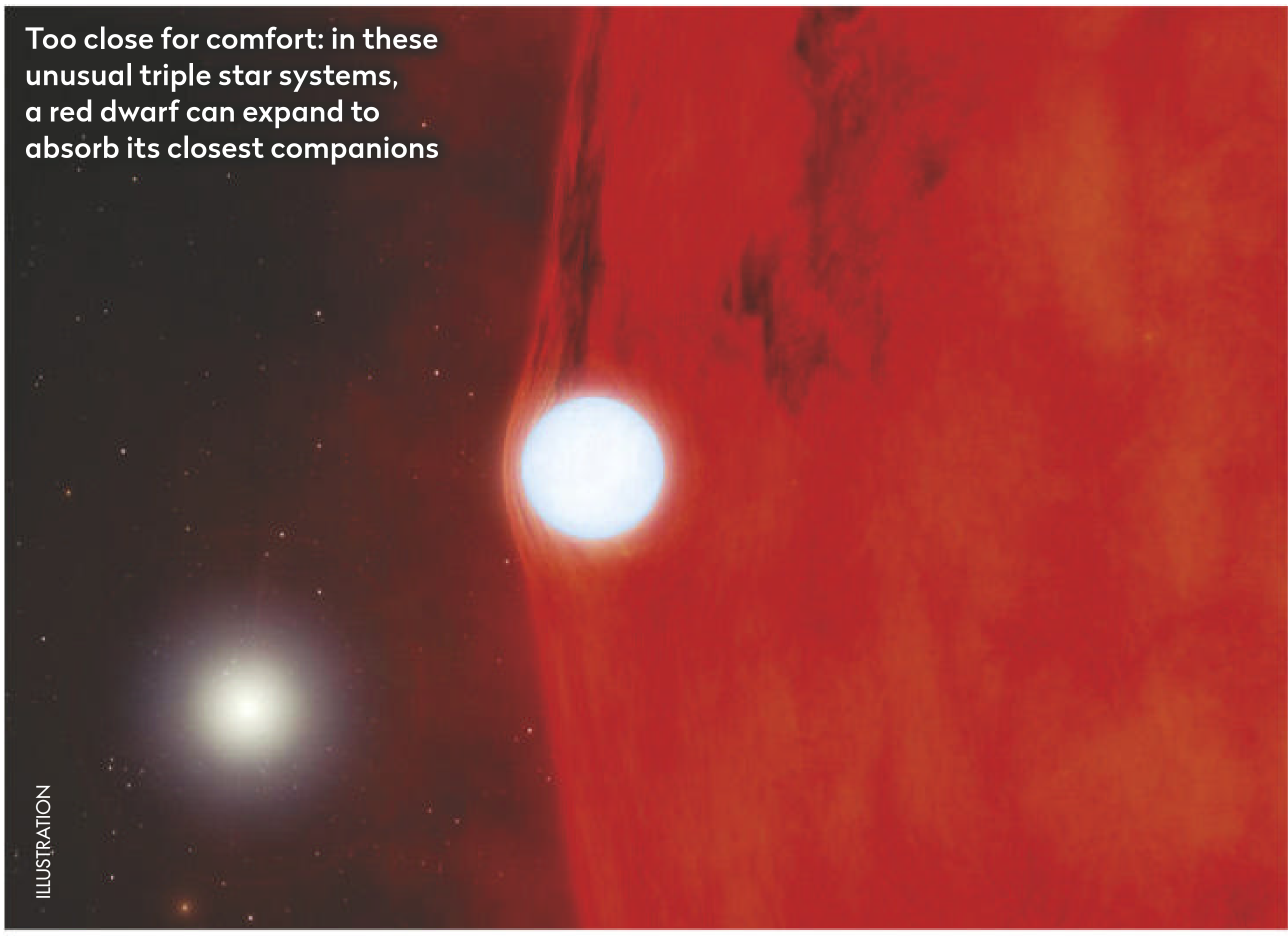
Expanding stars

Red giants can be enormous – the Sun in a similar phase of its evolution may well engulf the orbit of Earth – and in this particular system the star may be large enough, and the orbit of the two sufficiently close together, that it will absorb its closest companion. This scenario is made more likely by the gravitational influence of the outermost star.

"Most of these systems have two stars on a tight orbit around each other, and a third on a loose, outer orbit around the common centre of mass"

Once fuel at the core of this first star is exhausted it will shed its outer layers, to reveal the smaller companion star once more, and leave a white dwarf in a tight binary around the now recovered second star. The system has reverted to a triple system, but it won't be long before the outermost star in turn swells into its giant phase. If it is massive enough it will expand to engulf its binary companions, and at this point an interesting and unusual new process takes place. The effect of being in the gaseous envelope of the outer star allows the pre-existing white dwarf to strip the rest of the material from the smallest star. This parasitic behaviour turns the previous double into a single white dwarf, left to spiral towards the heart of the giant companion.

The end result will be a tight white dwarf binary or even, following a spectacular supernova and merger, a single giant white dwarf. In this latter case, what was a triple system would have produced a single remnant. Such a fate is not likely – maybe one in a thousand triple systems will evolve like this – but in the near future sky surveys may catch the glow of a supernova which is the result of this complex and fascinating story.



Too close for comfort: in these unusual triple star systems, a red dwarf can expand to absorb its closest companions

Chris Lintott was reading... *Parasite common envelope evolution by triple-star systems* by Noam Soker and Ealeal Bear. **Read it online at: https://arxiv.org/abs/2104.03850**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT

◄ **An astronomical treasure trove: among the historical gems at the Royal Astronomical Society Library is Ptolemy's *Almagest*, originally written in the 2nd century AD**

Sian Prosser is a librarian and archivist for the Royal Astronomical Society (RAS)

In May's *The Sky at Night*, **Sian Prosser**, the Royal Astronomical Society's librarian and archivist, showed Maggie how astronomers across the ages have mapped out the stars

When *The Sky at Night* asked if the Royal Astronomical Society (RAS) had any books in its library that show how people throughout history have measured the positions of stars – a field known as astrometry – I was happy to say, "Yes, we do".

After a year of very few visitors, it was a pleasure to show presenter Maggie Aderin-Pocock some of our oldest star catalogues and atlases for the May episode, in relation to the latest ESA Gaia mission data release, and to share these texts with *The Sky at Night*'s audience.

The first book we looked at was Ptolemy's *Almagest*, originally written in the 2nd century AD. It was a key textbook on astronomy for centuries and includes a catalogue of 1,088 stars. The next landmark in astrometry we looked at was a catalogue of 994 stars compiled by the Timurid ruler Ulugh Beg in 15th-century Samarkand, Uzbekistan. Originally copied by hand, astronomical texts like these began to be disseminated widely when printing technology was adopted in Europe. The RAS holds the first printed edition of the *Almagest* from 1515 and the 1665 edition of Ulugh Beg's catalogue, both important witnesses to the history of scientific publishing.

In the 16th century, the Danish astronomer Tycho Brahe developed more precise instrumentation, such as armillary spheres, and used these to make more accurate observations, albeit with the naked eye. The German astronomer and mathematician Johannes Kepler finally published the star catalogue based on Brahe's meticulous observations in the *Rudolphine Tables* in 1627, which encoded Kepler's laws of planetary motion in a heliocentric model of the Universe. The tables were so reliable they could be used to predict celestial events, including the transit of Mercury in 1631.

An eye for accuracy

Kepler and Brahe are famous in the history of astronomy, but Maria Cunitz is less well-known. A woman with the rare opportunity to learn astronomy and mathematics, she recognised the accuracy of the *Rudolphine Tables* but

ROYAL ASTRONOMICAL SOCIETY

saw their complexity as a flaw. She published simplified versions of these tables as *Urania Propitia* in 1650. Our rare copy of this book is a precious example of a high-level scientific text published by a woman under her own name during the period.

In the 17th century the first Astronomer Royal, John Flamsteed, and his contemporaries were able to use telescopes to see further than ever before. Flamsteed was tasked with creating more accurate star catalogues and atlases to improve navigation at sea. Published posthumously, Flamsteed's star catalogue contained 3,000 stars, tripling the number that were visible to astronomers like Ptolemy and Brahe. In the late 18th century, the astronomer Caroline Herschel revised Flamsteed's catalogue, one of many achievements for which she became the first woman to be awarded the Gold Medal of the RAS in 1828.

The RAS library contains works by pioneering men and women who charted the night sky. Many of our early Fellows were involved in the development of photography and astrographic telescopes, and their use in international projects such as the Carte du Ciel and the Astrographic Catalogue.

Our present-day members include men and women involved in the new era of space-based astrometry missions such as Hipparcos and Gaia. I hope that the RAS Library will serve as a repository for their work and as a space for people to learn about the development of astronomy for years to come.

Looking back: The Sky at Night

16 June 1984

On the 16 June 1984 episode of *The Sky at Night*, Patrick Moore took a trip to La Palma in the Canary Islands. He visited the Roque de los Muchachos Observatory, where dozens of telescopes take advantage of the clear skies and high altitude to observe the Universe. Among these was a 'new' addition – a 100-inch aperture reflector called the Isaac Newton Telescope.

▲ **From Sussex to the Canaries: the Isaac Newton Telescope**

In truth, it was only new to La Palma, as it had been observing the skies over Herstmonceux, Sussex since the 1960s. Unfortunately, the English weather was hampering the telescope's scientific ability and so in 1979, its operators began the process of transplanting it to La Palma. Over the next five years it was upgraded with a new mirror and a colour video camera to record observations, before being flown to its new home.

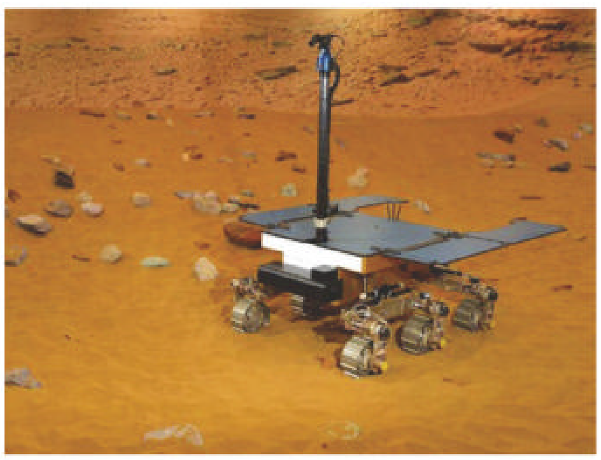
In 1984, Patrick was there to watch the Isaac Newton Telescope take its first light on La Palma by observing the Ring Nebula in Lyra.

It is still in use today, having gone through several upgrades. Meanwhile, the original site at Hertmonceux is now The Observatory Science Centre, which regularly puts on science and astronomy events for the public.

UK Space Engineering Special

Britain plays a significant role in space engineering, from its membership of the European Space Agency to its work designing and building robots that explore the Solar System. In this episode Maggie and Chris delve into the ways in which British engineering is helping us explore space, from Mars rovers in Stevenage to satellite testing in Oxfordshire.

BBC Four, **13 June**, 10pm (first repeat BBC Four, **17 June**, 7:30pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information



▲ **The Rosalind Franklin Mars rover was tested at the Mars Yard in Stevenage**

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize: four Philip's titles

PHILIP'S The 'Message of the Month' writer will receive a bundle of four top titles courtesy of astronomy publisher Philip's: Ian Ridpath and Wil Tirion's *Star Chart*, Robin Scagell's *Guide to the Northern Constellations*, Heather Couper and Nigel Henbest's *2021 Stargazing*, and a planisphere for the night skies as they appear at latitude 51.5° north.

Winner's details will be passed on to Octopus Publishing to fulfil the prize

A kite as high as the Moon

On 23 April, I was imaging the Moon during the day in our back garden, taking a video to give me some clear frames. I completed a total of about nine minutes of footage and, by a stroke of luck, a red kite flew between my camera and the Moon while I was recording!

I was able to track down the frames the red kite appeared in and stack them to produce an image of the bird in front of the Moon. I also took out my favourite single frame and saved it as an image on its own.
Jamie Hopkin, aged 14, via email

A great capture, Jamie. It brings a whole new meaning to 'lucky imaging'! ***– Ed***

Flying finish: Jamie's stacked image of the red kite and the Moon (above), and his stunning single frame

Tweet

Leona Kane
@Leonaa_x • Apr 26
Tonight's Super Pink Moon! The moon itself might not be pink, but the sky sure was. @VirtualAstro @AstronomyIRL @skyatnightmag @Failte_Ireland @EarthPix @RoyalAstroSoc

Where is it?

Please could you tell me the location of the picture on the front cover of the May 2021 issue of the magazine?
John Taylor, via email

Our cover image is a picture of Neist Point Lighthouse on the Isle of Skye. ***– Ed.***

Name that galaxy!

Chris Lintott asked readers to suggest a new name for a merger of the Andromeda and Milky Way galaxies. (Cutting Edge, 'When galaxies collide', April 2021, page 19). Here are your suggestions:

I was reading the article about the two galaxies colliding within the next 4.5 billion years. My suggestion for the new name is Milandroway. **Eric Loper, via email**

Just off the top of my head – Miland Way
Eva Frida, via email

Milkier Way
Faizan Mohammed, via email

In the distant future of the Universe two spiral galaxies will have merged to become

a much bigger elliptical galaxy: the Andromeda Way. No longer milky, since the splash of stars will have given way to a diffuse glow, the Andromeda Way will be a hint of something that once was, without giving away its true nature.
Nick & Kelly Soter, via email

How about Andrommilka?
Nii Allotey, via email

Alcaeus, one of Andromeda's sons. **Neville van Wageningen, via email**

If our previous habit of using Latin in our educated life continues then I think our new galaxy might be named in full as Via Lactea Corona Australis, or Lactea Australis for short.
Janvier Pousson, via email

The Big Join Elliptical or just the BJE. **Alan Cook, via email**

I suggest Andromeda Way; much better than the proposed 'Milkdromeda'.
Angela Burke, Dallas, US

'Milkdromeda' is awful – it has to be Galaxy McGalaxy Face! Even MilkyAndromeda or MilkAndromeda sound better.
Steven Forward, via email

The Andromedilky Way?
James Sireno, via email ▸

ON FACEBOOK

Remembering Michael Collins

Our Facebook page was flooded with messages following the news of the death of former astronaut and Apollo 11 Command Module Pilot Michael Collins. Many of you got in touch to remember his life:

Steven Andrews RIP Michael Collins and thank you for your service to humankind in the pursuit of space exploration.

David Tunnell To be absolutely alone while his mates were making the first step on the Moon; and with their safety in his hands to return home. RIP Michael Collins, the bravest of us all.

Amt Thompson Such sad news. Sincere condolences to his family and friends.

Brian Burke Sad news – he was a real gent and had a warm personality. He was such a massive achiever, but always very modest. I will always remember him.

Gordon Hogan It's so sad; I have just finished reading his updated autobiography. What a wonderful, modest and genuinely funny man.

John Bryson Sad News – the heroic pilot of Columbia.

Peter Grimes I loved Michael Collins's sense of humour from lecture podcasts. That just leaves Buzz Aldrin from that crew, and there are fewer of the others left each year; of the 12 moonwalkers just four are still alive and they are all 85-plus. The others are Apollo 15's Dave Scott, Apollo 16's Charlie Duke and Apollo 17's Harrison Schmitt.

Chris Moore Michael Collins's book, *Carrying the Fire*, has been my favourite book on spaceflight since I first read it about 35 years ago.

Toni Carmichael So very sad. RIP.

Jason Gonsalves To infinity and beyond, RIP and Godspeed Michael.

Mark Godwin Read his book. A wonderful man.

Mathew Howlett Sad news. RIP Michael Collins, a legend in his and humanity's lifetime.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies
With **Steve Richards**

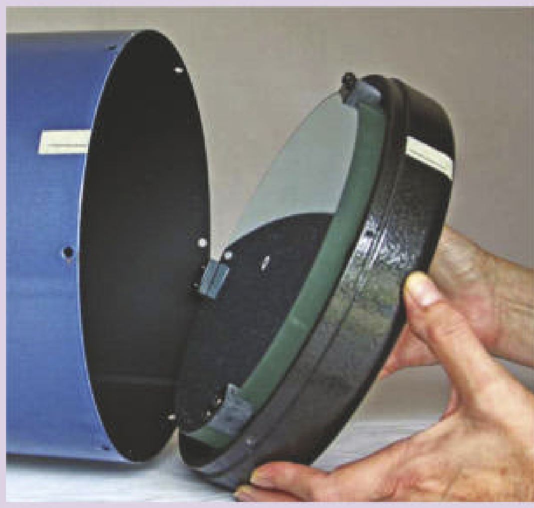
Email your queries to
scopedoctor@skyatnightmagazine.com

After cleaning my 8-inch Sky-Watcher Helios's mirror, I noticed the retaining clamps were very slack. How should I tighten them? PETER BOLT

Supporting the primary mirror in a Newtonian reflector is a more complex issue than you might imagine and modern telescope designers go to great lengths to produce supportive mirror cells.

Mirror clips are designed to simply stop the mirror from falling out and although some clips are designed to just rest on the bevelled edge of the mirror, careful adjustment is required to ensure that no pressure is exerted on the mirror as this can result in deformation and astigmatism. Using a 'business card' to set a space between the mirror and clip is a popular method for avoiding this issue. However, this doesn't avoid mirror slippage so shimming might at first appear to be the solution, but this too can deform the mirror and again introduce astigmatism.

The Helios mirror cell is a simple design, which is why the manufacturer originally used silicone to stop lateral movement. Try and duplicate their fixing method as closely as you can, as 2mm of slippage will cause all sorts of collimation issues.



▲ **Supporting the primary mirror in a Newtonian reflector needs care**

Steve's top tip

What are diffraction spikes?

When light from a bright object like a star passes across any straight edge it is bent or 'diffracted' very slightly and this diffraction is manifested in the form of bright spikes extending from the core at 180° from one another.

A typical example of this is the bright lines produced by the spider vanes that support the secondary mirror in a Newtonian reflector, where each vane produces two spikes. Most secondary mirror supports have four vanes, but you only see four spikes because the second set are coincident with the first. However, a spider vane with only three vanes will clearly show the 'missing' spikes resulting in six spikes being visible.

Steve Richards is a keen astro imager and an astronomy equipment expert

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Instagram

Balders18 • 27 April

Last night's Pink supermoon from the Isle of Grain looking at Sheerness docks, Kent @bbcskyatnightmag @visitkent @astrobackyard @maritimecoastguard #lunar #pinkmoon #supermoon

▸ The merger makes the Zagreus Galaxy, after the Greek goddess of rebirth.
Colin Merriott, via email

Drama way.
Leon Hill, via email

The galaxies may be called Androlacita: Lacita being Latin for Milky Way.
Sukina Natarajan, via email

Andromilka galaxy. That is all.
Connor Wathen, via email

Catching the Sun

At the start of March I tried some solar shots. Even though the Sun is at a solar minimum I thought I might hit lucky. I had a piece of Baader solar film left over from an old project, so I used the method shown on your website to make a cardboard filter for my scope to fit the off-axis hole in the lens cap. Next, using my ZWO ASI120MC planetary camera I shot a video and processed it in AutoStakkert! and RegiStax.

I was surprised to catch a rare sunspot and even some granulation. Not bad for a £5 homemade filter!
John Consadine, Dereham, Norfolk

▲ **From left: John's solar filter (made using certified solar film) and his sunspot image**

SOCIETY IN FOCUS

Orwell Astronomical Society (Ipswich), or OASI, was founded in 1967 and has provided a focal point for astronomy around the area since then. The interests and activities of members are diverse: from astrophotography, radio astronomy and astronomical history to eclipse-chasing, fireball-tracking and public outreach.

Fortunately, the COVID-19 pandemic has not diminished the enthusiasm of our society; images of deep-sky objects and videos of trains of satellites are regularly circulated to members. OASI has hosted over 80 online meetings and talks, both live and recorded. This online activity has enabled us to invite our friends from neighbouring societies to join in, and in turn we have been invited to some of their activities. We hope this collaboration will continue after the pandemic recedes.

OASI is based at Orwell Park Observatory, a Victorian observatory that is now part of a school. It has an original 10-inch Troughton and Simms refractor. We are looking forward to welcoming members back to resume our public open nights and private visits to the dome.

▲ **OASI members bring astronomy to the masses at the Latitude Festival in 2019**

Public outreach is a large part of OASI's activity. Beyond the usual star parties we have attended science festivals, historical re-enactments and museum exhibitions; and we have even been Chris Lintott's 'support act' at Latitude Festival!

See our website for more details about OASI and its outreach activities.
Paul Whiting, OASI Treasurer
▸ **www.oasi.org.uk**

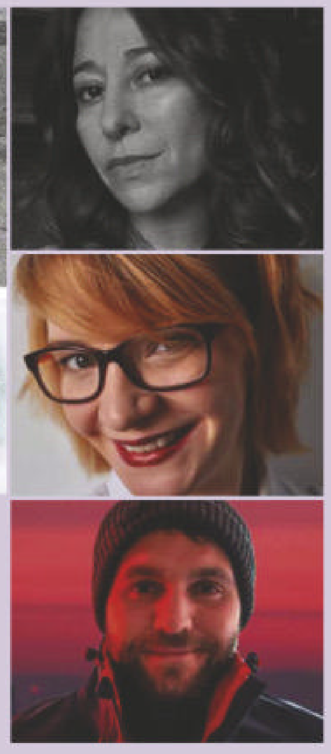
COVID-19

Online and socially distanced events taking place this month

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON

PICK OF THE MONTH



▲ Capital benefits: this year's Edinburgh Science Festival boasts expert speakers covering a wide variety of subjects for all ages

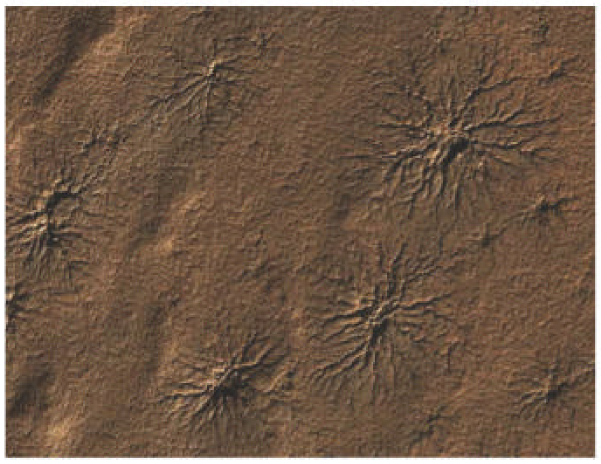
Online Edinburgh Science Festival

This year it's an online affair, with plenty of astronomy treats, from 26 June–11 July

Physical events are restricted, but there's a full programme of digital offerings from the annual science festival this year, including lots for astronomy fans to enjoy. Confirmed are presentations by Professor Janna Levin of the fantastic *Black Hole Survival Guide*, Professor Emily Levesque on the hidden world of the professional astronomer, and a look at *The First Stars* that lit our skies with Professor Emma Chapman. For younger space enthusiasts, Tom Kerss will be chatting about *You Can Explore the Universe*, his brand new how-to book for budding astronomers.

If you're out and about in Edinburgh, look out for works from The Space and Satellites artist residency, an initiative producing creative works based on satellite data, and Dynamic Earth will be launching its new planetarium.

The full programme is available from the end of May at **sciencefestival.co.uk**



NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA

CITIZEN SCIENCE

Online Planet Four: Terrains

Spot 'baby spiders', 'channel networks' and 'swiss cheese' as part of this project to analyse the Red Planet's south polar region using images from the Mars Reconnaissance Orbiter.
bit.ly/planetfourterrains

PODCAST

Online Star Diary

Get pointers on the best objects to see in the night sky each month with *BBC Sky at Night Magazine*'s new monthly podcast, featuring long-time reviews editor Paul Money.
www.skyatnightmagazine.com/podcasts/star-diary

TALKS

Online Scope It Out

27 May, 10:30am

A one-hour workshop for primary school children (suitable for Year groups 5 and 6; ages 9 to 11) about the James Webb Space Telescope, with worksheets and hands-on practical tasks using household objects. The event is free and takes place via Zoom; you can book places at **bit.ly/scopeitoutworkshop**

Online The Extremely Large Telescope: What, Why and How?

7 June, 7pm

Sandi Wilson's online talk explores the engineering behind the Extremely Large Telescope. Currently being constructed high in the Atacama Desert, Chile, it will be the largest optical and infrared telescope in the world, and includes instruments built at the Royal Observatory Edinburgh. You can book at **bit.ly/ELTWhatWhyHow**

Live Exploring the Solar System in Otford

Otford Station, 8 June, 2pm

It's muddy near Pluto, so boots are recommended for this walking tour around the Kent village of Otford, where a model of the Solar System was created in 2000. Visit each planet in turn for a mind-blowing illustration of the scale of space. £12/£9. You can book places at **bit.ly/Otfordexploringthesolarsystem**

Live From Apollo to the Space Shuttle

Goostrey Village Hall, 15 June, 8pm

Macclesfield Astronomical Society hosts Rod Woodcock (British Interplanetary Society) for his talk 'From Apollo to the Space Shuttle – with a Glimpse into the Future of Spaceflight'. **maccastrosoc.com**

Live Solar Sunday

Kielder Observatory, 6 and 20 June, 7pm

An early evening session observing and discussing the Sun at Kielder Observatory, with hot drinks supplied. Adult £25/ concessions £23. Book tickets at **kielderobservatory.org/index.php?**

Nestled deep in Kielder forest in Northumberland, Kielder Observatory runs stargazing and educational events for the public to experience astronomy. We have a fantastic array of telescopes for exploring some of the darkest skies in the UK, and our events are packed full of inspiring talks, imagery and activities. All ages are welcome, booking is essential though the official website.

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FIELD OF VIEW

How strong will the new solar cycle be?

Alexandra Hart reflects on the different forecasts for observing Solar Cycle 25

KOUZOU SAKAI/FOLIO

Alexandra Hart is an avid solar observer and imager from the UK, and three times winner of the 'Our Sun' category in the Astronomy Photographer of the Year competition

When the days start to lengthen and the hours of darkness decrease, we all get the itch to dust off our solar telescopes. However, they might be more dusty than usual at the moment, considering we have been in solar minimum for the past couple of years. But things are starting to happen; the Sun is waking up and Solar Cycle 25 is just starting to come to life. During 2020 we started to see new-cycle active regions appear with regularity, and late in that year there was an increase in activity in the Sun's southern hemisphere. For solar astronomers everywhere the excitement is mounting and the telescopes are stirring; the question on everyone's mind is 'How strong or weak will Solar Cycle 25 be?'

Well, to be honest I don't think anyone knows. Solar scientists seem to have struggled to predict the strength of sunspot cycles in the past because we currently don't understand enough about the mechanism that drives the cycle. Without knowing the fundamental factors that underlie the formation and strength of the solar cycle we cannot predict it. This past six months has demonstrated this with the publication of two papers, one predicting that Solar Cycle 25 will be the weakest on record and another predicting it will be one of the strongest. I am sure the solar scientists will continue to thrash out their theories and models, but only time will tell as the solar cycle progresses who will be in the winning camp.

Maybe solar cycle forecasting is similar to weather forecasting: all the scientific modelling and computers in the world can't seem to get it right. Only recently I had a forecast for sunshine all day, so of course it was cloudy all day. The next day was predicted to be cloudy, so of course it was sunny. This is probably because of the well-known factor of Sod's law.

I discovered early on in my solar observing days that sunny days only occurred when at work during the week, and weekends were always cloudy. If an amazing sunspot appeared on the Sun we would be under permanent clouds for weeks. I even went as far as to chart this effect for four months and found that Wednesdays and Thursdays were three times more likely to be sunny than a weekend! Maybe something we don't understand yet is going to influence the solar cycle strength, and perhaps because we have all invested in solar telescopes the Sun will have its weakest solar cycle on record. I remain optimistic though; Solar Cycle 25 has ramped up activity faster than when I observed Solar Cycle 24 a decade ago.

So, what will the next cycle, Solar Cycle 25, be like? Some say a weak one, some say a strong one, but I guess we'll have to wait and see. It's a bit like the weather forecast; never trust any of them until you look out of the window yourself.

▸ **To find out more about Solar Cycle 25 see page 28**

BBC

Sky at Night MAGAZINE

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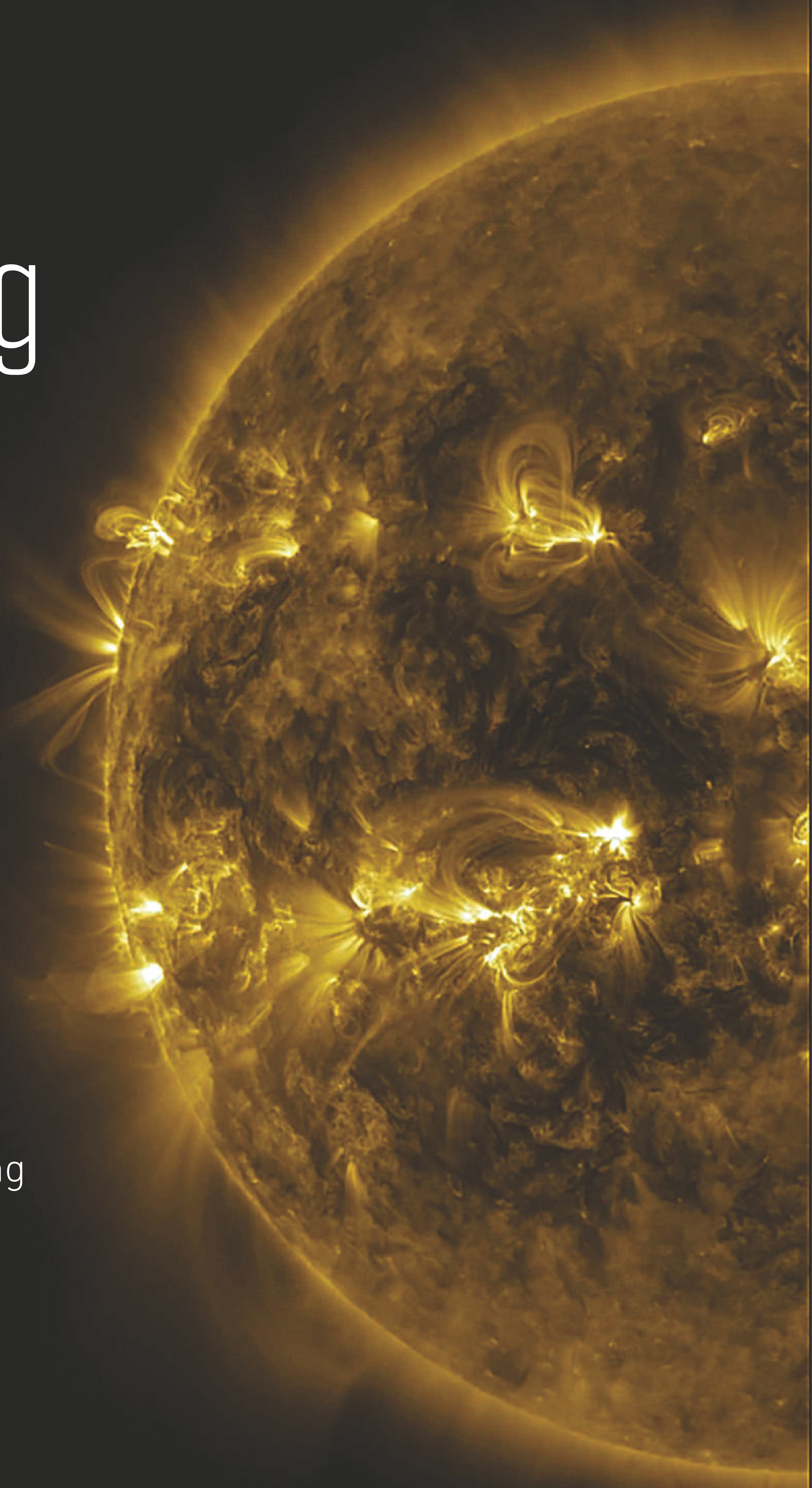
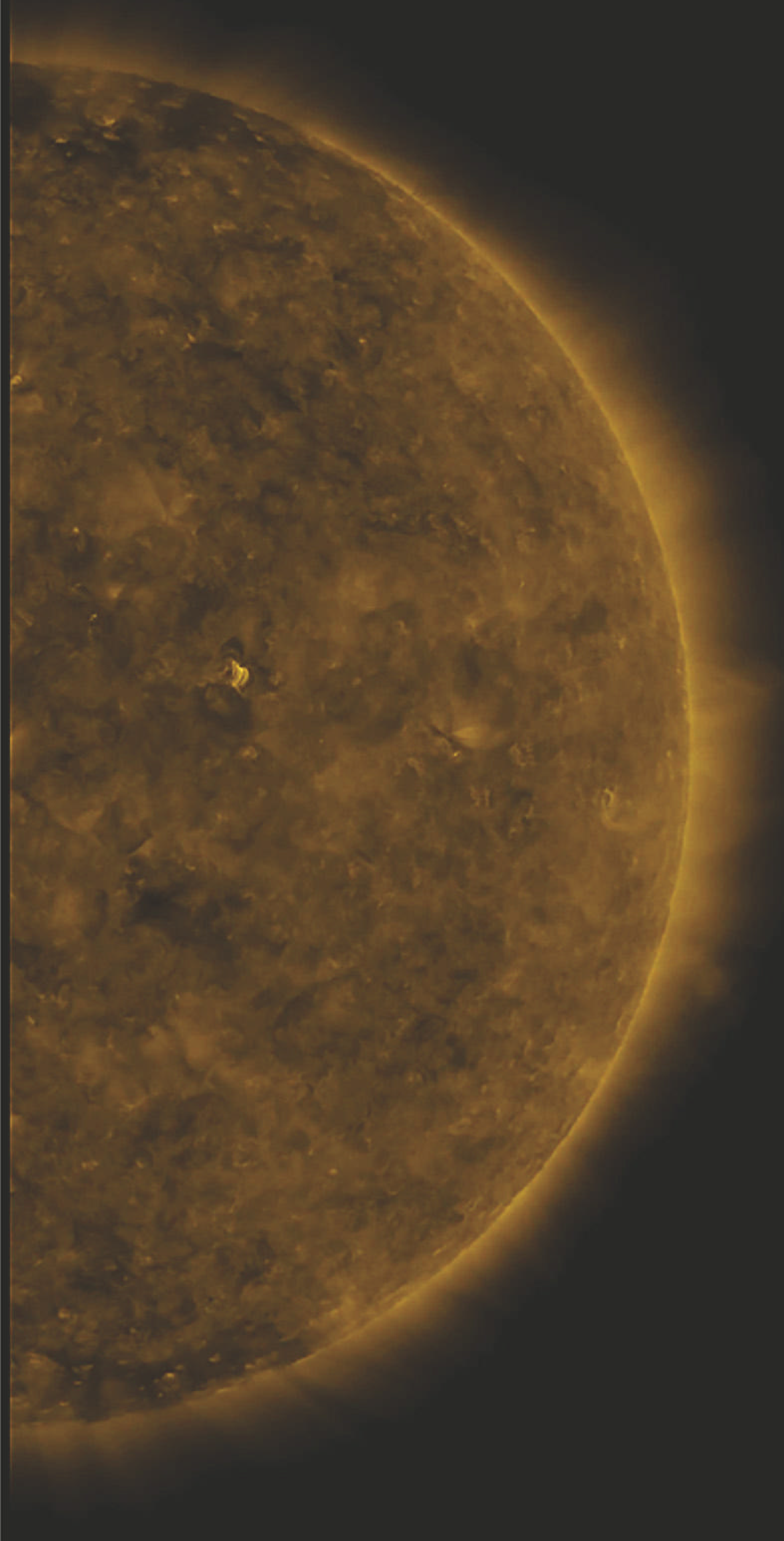
Predicting the Sun's SOLAR CYCLE

With the Sun slowly awakening from a recent minimum, **Stephanie Yardley** investigates the process of forecasting solar activity



Two sides to the Sun: a comparison of solar activity at the height of Solar Cycle 24 in April 2014 (left) and at solar minimum in December 2019 (right)



NASA/SDO

The Sun is an active place; sometimes it's calm, while at other times it's far stormier. But is there any way that we can forecast our nearest star's activity?

Our current understanding of the Sun comes from centuries of observations. Naked-eye observations of sunspots were first made in ancient times. either during cloudy conditions, after sunrise or before sunset – a dangerous practice that risked serious damage to eyesight, even blindness, despite reducing the Sun's glare enough to make sunspots visible.

Since the mid-1800s, long-term records of sunspots have been made by many scientists and amateur astronomers, revealing that the number of sunspots varies cyclically over an 11-year period known as the solar cycle.

Sighting sunspots

There is still some controversy surrounding who first observed sunspots, but the German medical student Johannes Fabricius was the first to publish his scientific findings. In 1611, after taking his first telescopic observations of the Sun, Fabricius teamed up with his father to track the motions of sunspots across the Sun's surface.

Despite the invention of the telescope, sunspots could still only be viewed shortly after sunrise or before sunset, and the considerable risk of eye damage remained. (Today we know never to look directly at the Sun without proper protection – eclipse glasses or a certified solar filter on optical equipment – no matter what time of day.)

The Fabricius father-son duo adopted a safer technique, previously devised by Johnnes Kepler (1571–1630) to observe what he mistakenly thought was the transit of Mercury. They used a camera obscura, a pinhole opening that projects an image of the Sun – still often used during solar eclipses today.

The Fabricius team correctly suggested that sunspots were features of the Sun itself, rather than clouds in the Sun's atmosphere or transiting ▸

▸ planets, and that these features moved in the same direction, eventually disappearing off the Sun's surface to reappear a few weeks later.

The discovery of the solar cycle came later, thanks to pharmacist, amateur astronomer and botanist Heinrich Schwabe. By continuously monitoring the number and location of sunspots between 1825 and 1843 he noticed a cyclic variation. Schwabe's findings encouraged Swiss astronomer and mathematician Rudolf Wolf to go one step further. Wolf combined his own regular sunspot observations with past records and reconstructed the sunspot cycle back to 1755. This became known as Solar Cycle 1 with all successive cycles being numbered accordingly.

For years scientists routinely recorded the size, number and position of sunspots without understanding their true origin. Then in 1908 George Ellery Hale, founder of the Mount Wilson Observatory, used a 60ft (18m) solar telescope to determine their magnetic nature. Hale made the first detection of magnetic fields beyond Earth by using the Zeeman effect – the splitting of several spectral lines caused by the presence of strong magnetic fields. This was the first indication that the Sun's magnetic field is the powerful driving force behind the solar cycle.

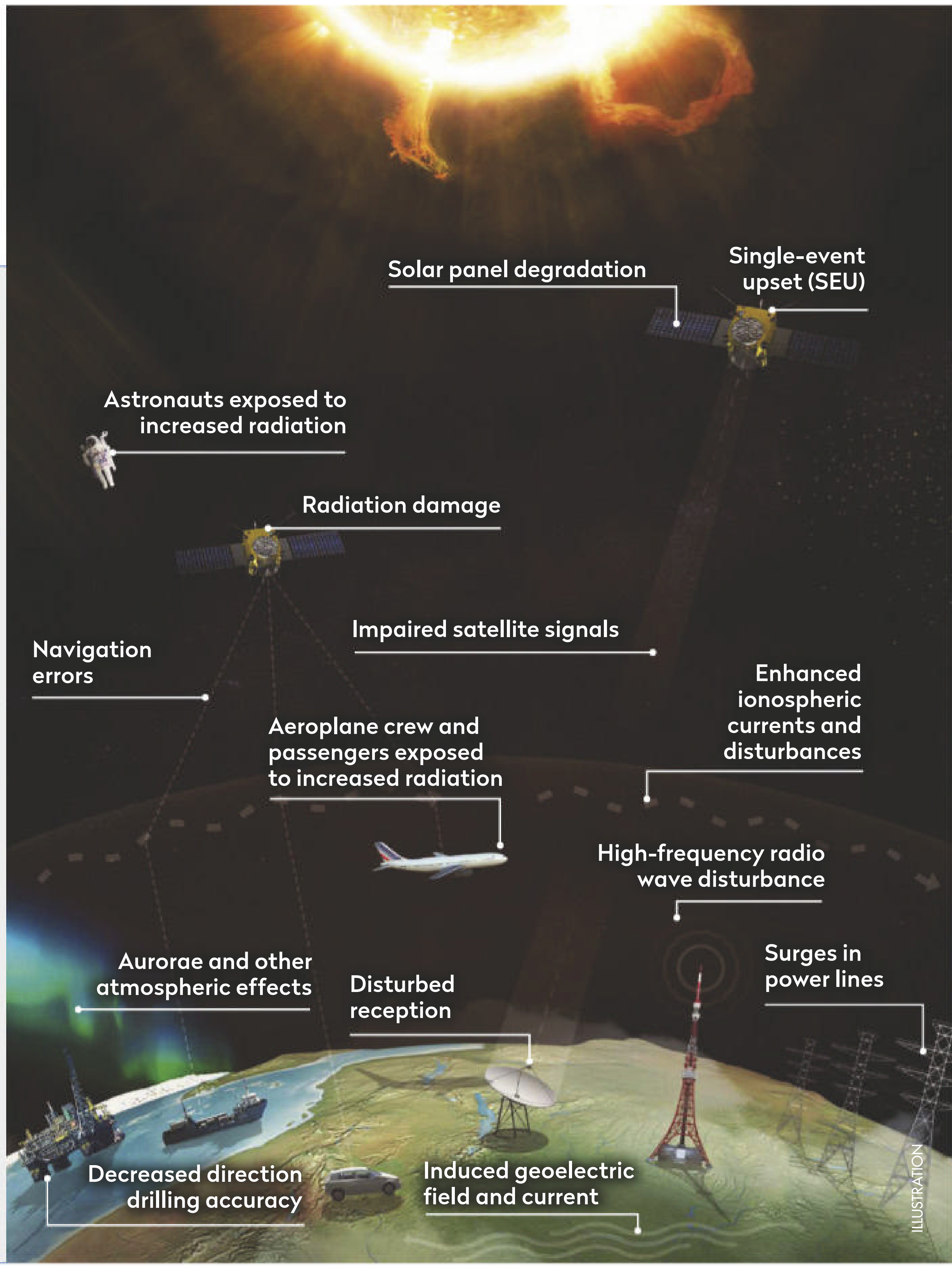
Powering the Sun

The mechanism that describes the appearance, evolution and destruction of these magnetic fields is known as the solar dynamo. It describes how the Sun modulates its large-scale magnetic field over astronomical timescales due to fluid motions. The dynamo operates in the Sun's convection zone and can account for all stages of the solar cycle.

At the beginning of a solar cycle, during solar minimum, the Sun's global magnetic field is aligned

ESA/SCIENCE OFFICE/CC BY-SA 3.0 IGO, PETE LAWRENCE, STEPHANIE YARDLEY

▼ **Knock-on effect: many business sectors can be affected by adverse space weather**

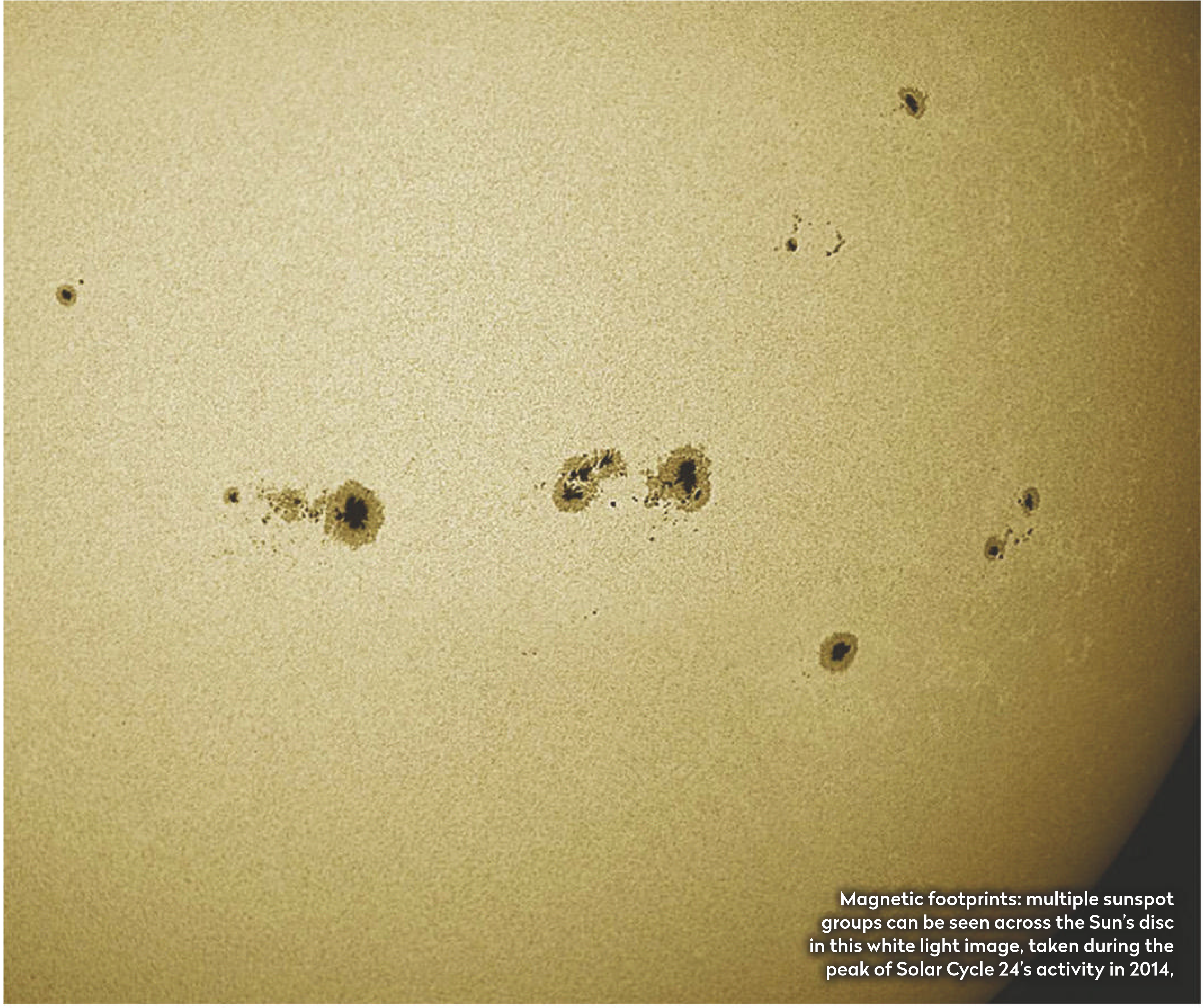


What is space weather and why does it matter?

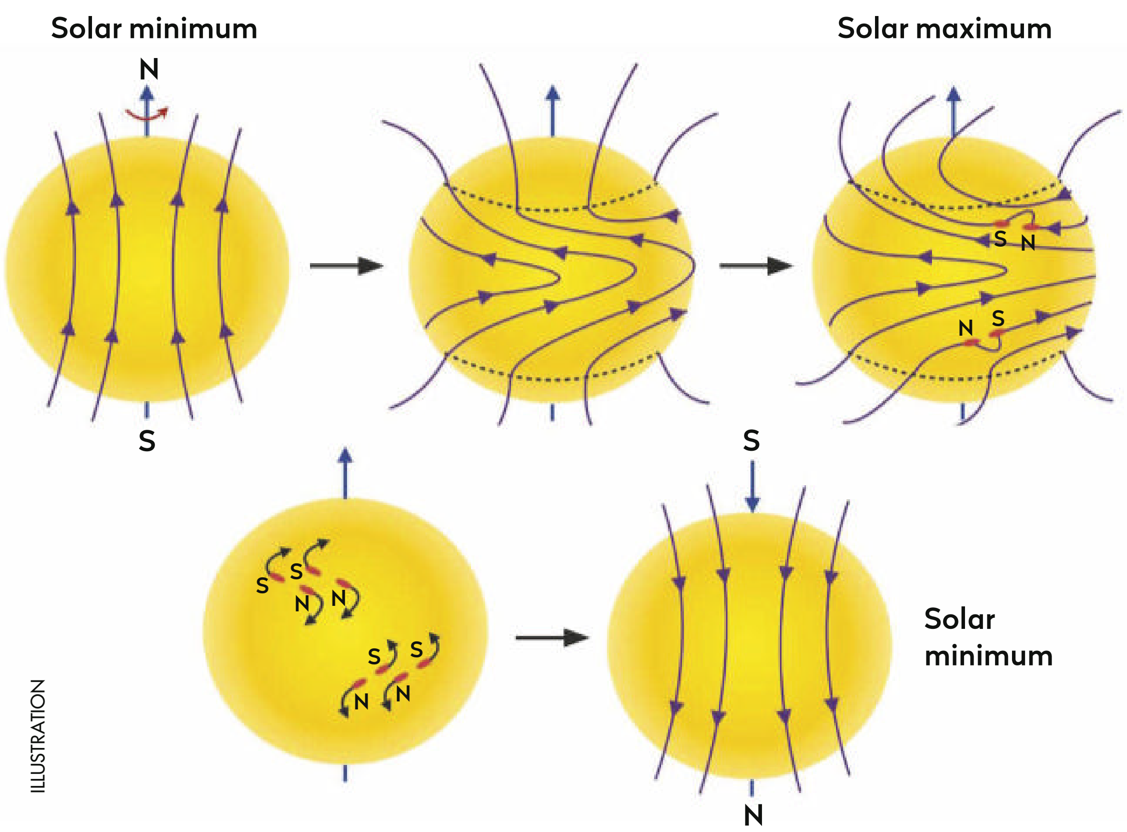
The activity of the Sun, 150 million km away, can have a big impact on Earth

The frequency of solar activity, such as solar flares and coronal mass ejections, increases at solar maximum and alters what we can expect in terms of space weather. Space weather describes the ever-changing conditions in the near-Earth environment due to the arrival of magnetic fields, radiation and high-energy particles that have been ejected from the Sun. The Sun's interaction with Earth's magnetosphere and upper atmosphere can produce dazzling auroral displays, but can also cause hazardous space weather conditions. Space weather can disrupt GPS navigation, cause radio blackouts, damage spacecraft and satellite electronics, and pose a severe radiation risk to crewed spaceflight.

To protect ourselves and mitigate the risk to our technological infrastructure we need to forecast these events prior to their occurrence. The current forecasting approach is to observe an eruption on the Sun and use data-driven modelling to predict its arrival time. But current forecasting methods do not provide enough warning ito protect our technological assets; the National Grid, for example, requires an advanced warning of three to five days.



Magnetic footprints: multiple sunspot groups can be seen across the Sun's disc in this white light image, taken during the peak of Solar Cycle 24's activity in 2014,



▲ **A solar dynamo: because the Sun spins faster at the equator than near its poles, its magnetic field stretches and makes loops – this is where sunspots form in north and south pairings**

north–south. As the Sun's rotation varies with latitude, a faster rotation rate near the equator drags the magnetic field until it becomes increasingly aligned east–west.

All this twisting and stretching strengthens the magnetic field, and once it is strong enough, sections of it become buoyant and emerge as loops through the Sun's surface. It is at the footpoints of these magnetic loops that sunspots appear, in pairs, one representing the north and the other the south magnetic pole like a bar magnet.

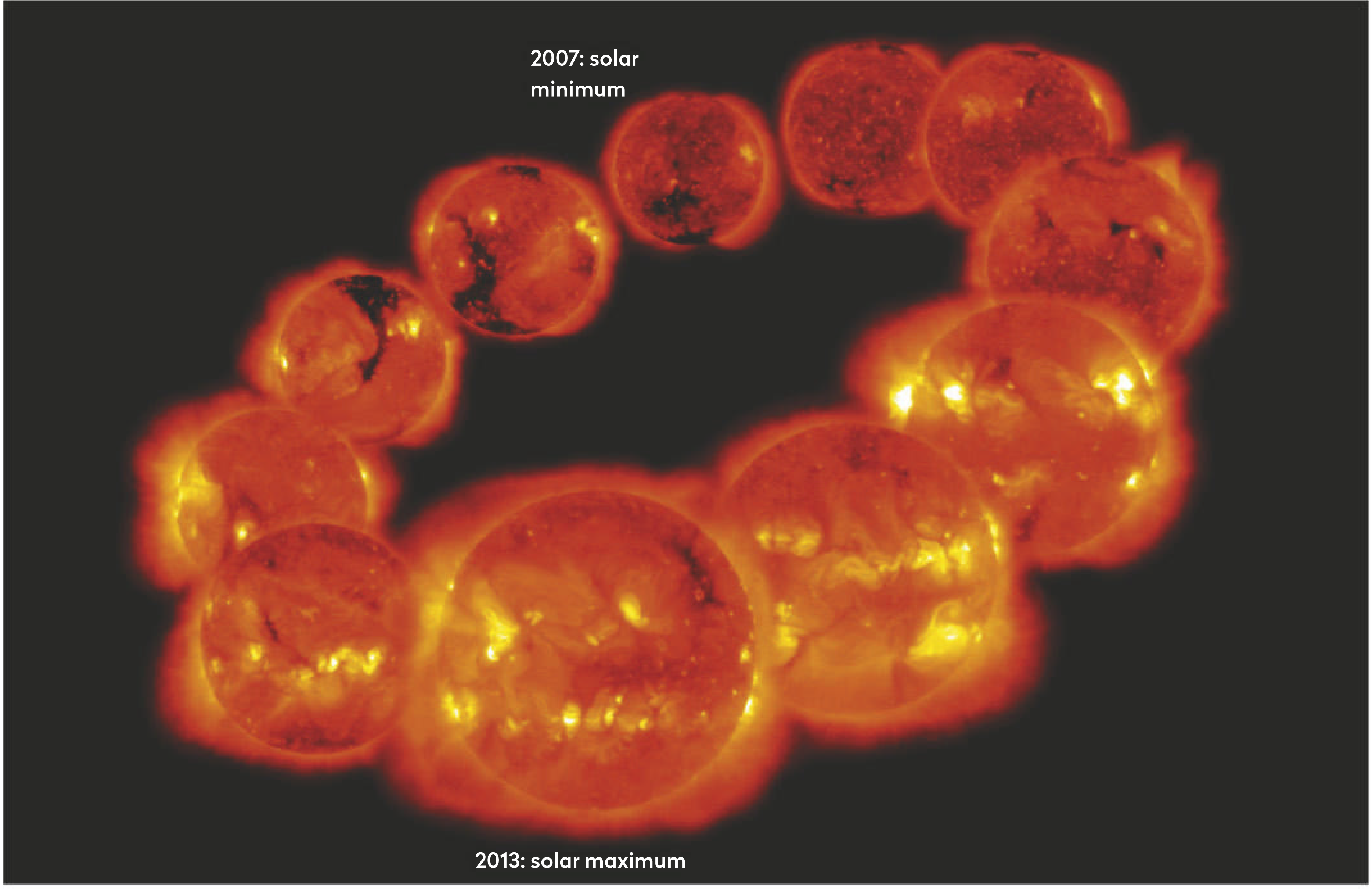
Sunspots first appear at high latitudes at solar minimum, when the new cycle is starting, forming more frequently and progressively lower as the solar cycle advances. Sunspot pairs are also tilted – the leading sunspot of the pair is located at a lower latitude, with a polarity matching the direction of the closest pole. The partner spot meanwhile follows behind and is polarised in the opposite direction to the pole. The tilt in the pairs comes from the twisting of the magnetic field caused by the Sun's rotation.

Over time, the sunspots are torn apart by surface flows that act in all directions. A latitudinal flow (moving from pole to pole on the Sun) transports the remaining fragments of the magnetic field from the trailing spot up towards the pole, where they neutralise and replace the existing polar fields with a magnetic field of opposite polarity. Eventually, around the peak of the cycle, this causes both of the Sun's poles to flip. Activity then decreases until the Sun is back to solar minimum.

After 11 years the whole cycle starts again, only with polar fields aligned in the opposite direction. And just to add further complexity, the Sun also undergoes longer fluctuations over 90, 200 and 2,400 year-timescales that can weaken or strengthen activity.

Prudent predictions

Scientists still do not yet fully understand the behaviour of the magnetic field inside the Sun, so solar cycle prediction is extremely challenging. Since ▸



▸ 1989 the NASA-NOAA Solar Cycle Prediction Panel, a panel of experts from across the world, has met every decade to discuss the various methods and release an official prediction for the upcoming cycle.

"Solar cycle predictions have a chequered history, particularly for the recently concluded Cycle 24," says Professor Dibyendu Nandi from the Indian Institute of Science Education and Research-Kolkata, a solar physicist who studies the solar magnetic cycle. "Wildly diverging predictions, the inability of the panel to reach an early consensus and a revision of its forecast has led to a scrutiny of the science of solar cycle predictions."

Given the great difficulty of the task and the fact that there is still much to learn to accurately forecast future cycles, the most recent prediction suggests that our current cycle, Cycle 25, will be weaker than average, on a par with the previous one, Cycle 24.

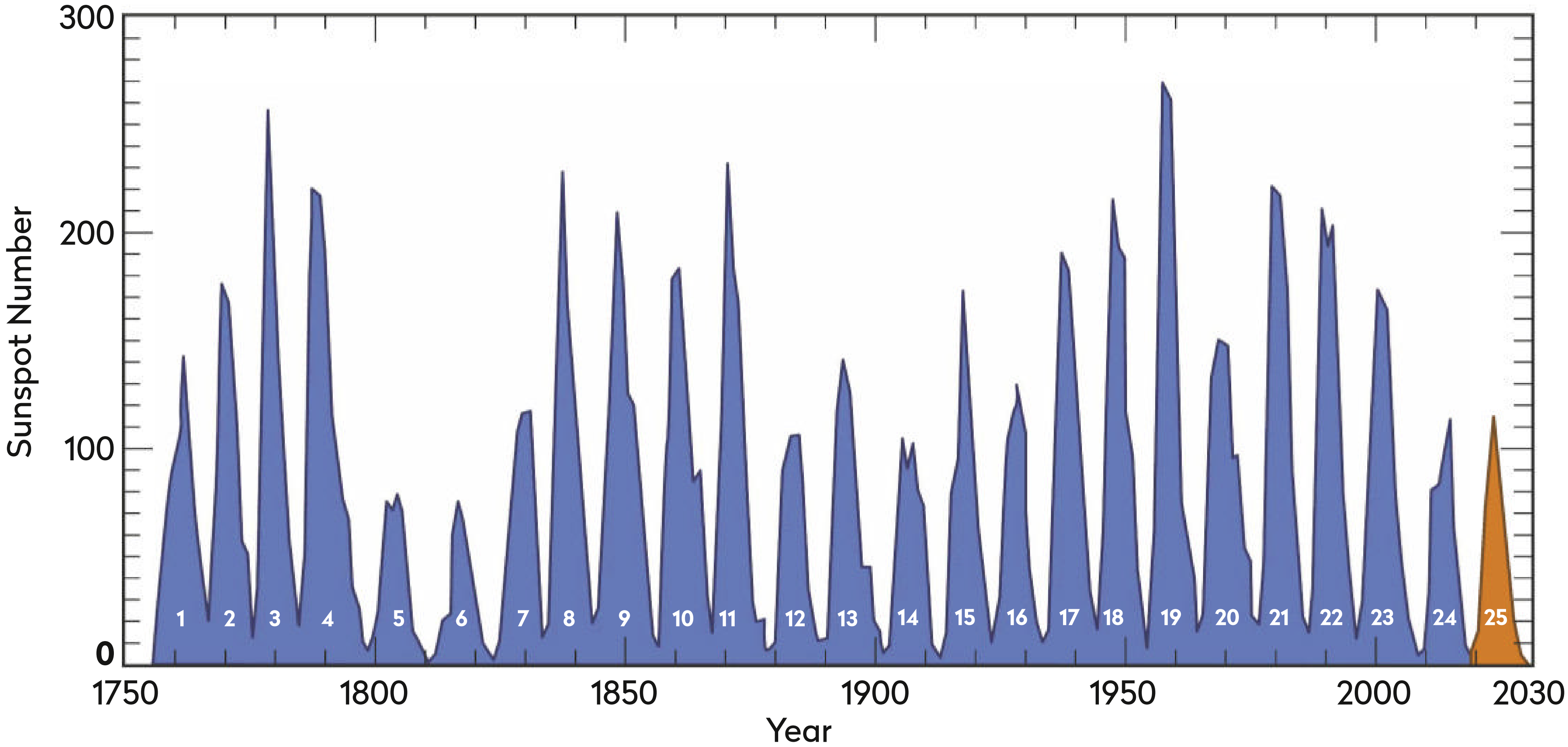
For Solar Cycle 24, the Prediciton Panel was split and could not come to a consensus, initially issuing a prediction that would either be moderately strong or weak. In April 2014, Cycle 24 peaked with a sunspot number of 113; it was the fourth weakest cycle since records began and weakest for a century.

Many different methods are used to provide the prediction. For Cycle 25 the panel considered 61 predictions that fell into seven different categories.

"After reviewing all of the available predictions, the panel agreed that physics-based methods had proven to be the most successful in the past," says Dr Lisa Upton, solar scientist at Space Systems Research Corporation, Colorado and co-chair of the NASA-NOAA Prediction Panel. This meant that the panel came to a consensus prediction fairly easily for Solar Cycle 25.

▲ Increasing solar activity is clear in this montage of the Sun in X-rays, showing each year of Solar Cycle 24 from minimum in 2007 clockwise through 2013's maximum

▼ Solar cycles and sunspot numbers (blue) from Solar Cycle 1 in 1755 to today. Predicted sunspots for the current Cycle 25 are shown in orange



Extreme solar events

While the Sun is constantly active, certain events stand out for their ferocity

THE CARRINGTON EVENT

In 1859, astronomer Richard Carrington noticed two patches of light emanating from a sunspot group – the first observation of a solar flare. The event was associated with a coronal mass ejection that arrived at Earth in 17.5 hours. Telegraph operators received shocks and aurora was visible as far south as Cuba.

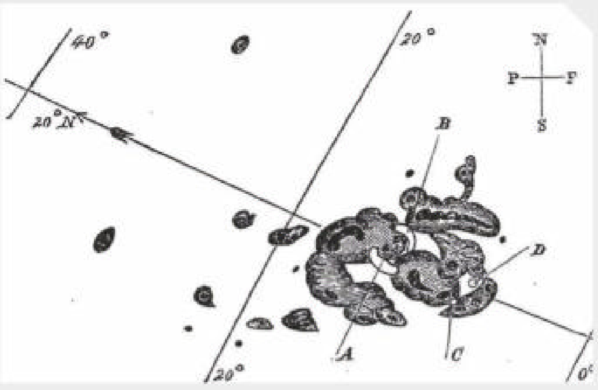
THE NEAR MISS

In July 2012, the Sun launched multiple coronal mass ejections that were comparable to the Carrington Event. If the eruptions had occurred one week earlier, they would have hit Earth, causing power outages. This would have left millions unable to watch the London Olympics and caused damage to the power grid.

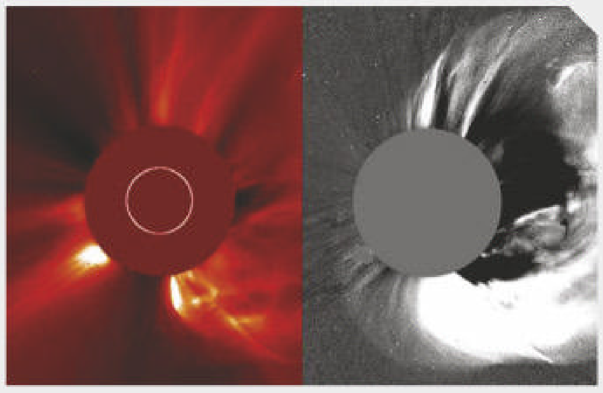
ST PATRICK'S DAY STORM

On 17 March 2015, St Patrick's Day, three days before a very cloudy total solar eclipse in northern Europe, a coronal mass ejection hit Earth, sparking wonderful displays of the aurora.

At the time it was the strongest geomagnetic storm of Solar Cycle 24, and was followed by a storm in October 2015.

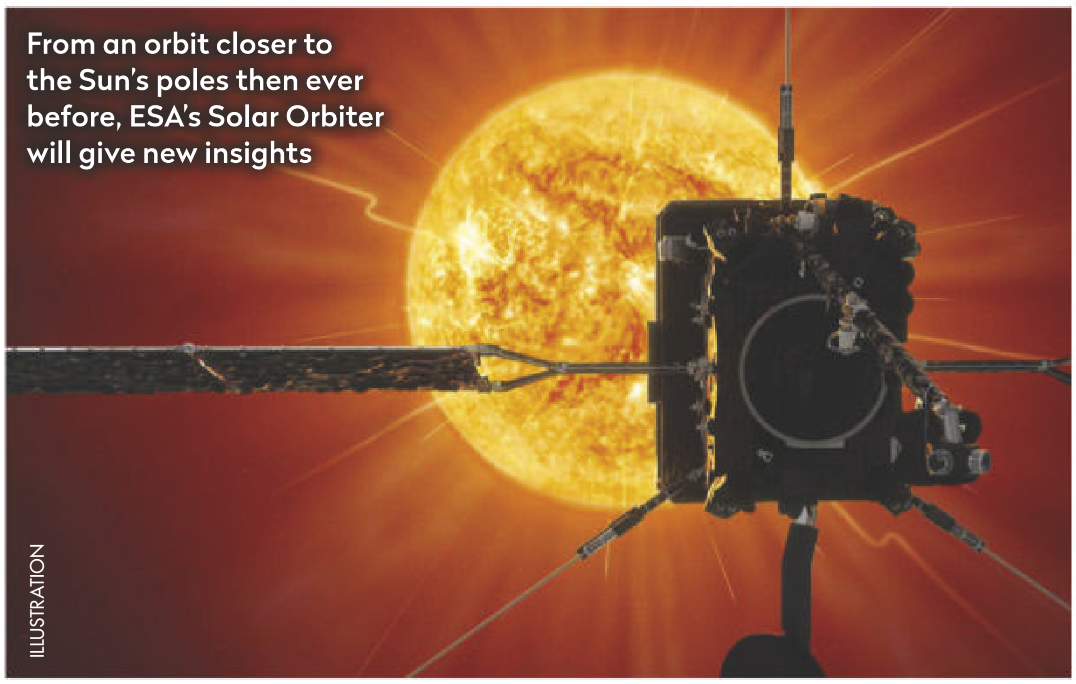


▲ A diagram by Richard Carrington from 1 September 1859, which included "patches of intensely bright and white light"



▲ Images from the Solar and Heliospheric Observatory (SOHO) from July 2012 show the Sun's coronal mass ejections

▲ Beautiful auroral displays – like this one above Jukkasjärvi in Sweden – were a result of the geometric storm in March 2015



From an orbit closer to the Sun's poles then ever before, ESA's Solar Orbiter will give new insights

ILLUSTRATION

Dr Stephanie Yardley is a post-doctoral research fellow based at UCL's Mullard Space Science Laboratory

These prediction methods build on what we think is happening inside the Sun and on the surface, along with observations to predict what will happen.

"We have made meaningful progress over the last decade," says Dibyendu. "This is reflected in all the physically well-grounded solar cycle models indicating a weak Solar Cycle 25. I am eagerly waiting for observational verification of our theoretical prediction models, but the Sun could yet again surprise us and send us back to the blackboard!"

Solar minimum was predicted to occur between October 2019 and 2020 with the cycle reaching a maximum around July 2025, plus or minus six months, with a peak sunspot number of 115. It has since been determined that solar minimum occurred in December 2019, when the appearance of new sunspots at high latitudes, with an oppositely orientated polarity, gave the signal that the new cycle had officially begun.

"With solar minimum occurring near the start of our predicted range, we might expect maximum to also occur closer to the beginning," says Upton. "We are still on track for Solar Cycle 25 to be on a par with Solar Cycle 24."

Does this mean that we are heading for a prolonged period of low solar activity, though? Perhaps not, as some solar scientists are predicting that this Solar Cycle 25 will actually break the trend of decreasing activity, with future cycles becoming more active.

"While this means that we have another fairly weak cycle ahead of us, the downward trend from Solar Cycle 22 to 24 has levelled off," suggests Upton.

This is good news for solar scientists and amateur astronomers, as we may expect to see a more active Sun in future cycles. "I'm excited to see what Solar Cycle 26 might have in store for us," says Upton. "While it's still far too early to say, we might see the solar cycles picking up in strength again."

In the meantime, ESA's Solar Orbiter, a 10 year-long mission to look closely at the Sun, should provide us with a missing part of the puzzle. During solar maximum the spacecraft will image the Sun's polar fields from a high viewpoint for the first time. These views should provide an insight into the inner workings of our star, meaning that in the future we can predict what the solar cycle will be like better than before.

JAXA/NAOJ/NASA/SAO, SUNSPOT GRAPH BY PAUL WOOTTON/ DATA COURTESY OF THE SIDC, BRUSSELS, BELGIUM AND W. DEAN PESNELL, SOHO/ESA & NASA, OLIVER DIXON/ALAMY LIVE NEWS, ESA/MEDIALAB

Parliament's plan to preserve DARK SKIES

A group of MPs from across the political spectrum is aiming to strengthen the law around excess lighting. **Jamie Carter** looks at its recommendations to reduce night blight

Despite a reduction this year, light pollution in the UK has been steadily worsening. Yet it's one of the most preventable and readily fixable types of pollution around. Now MPs have formed a new All-Party Parliamentary Group for Dark Skies (APPG) (**appgdarkskies.co.uk**) in the UK Parliament, dedicated to reducing light pollution across the country. Its aim: to put light pollution on a par with noise pollution, for which many statutory laws exist.

The APPG is being spearheaded in the House of Commons by Andrew Griffith, Conservative MP for Arundel and South Downs – home of the South Downs Dark Sky Reserve – and in the House of Lords by Martin Rees, the Astronomer Royal and a former President of the Royal Society.

The group's 10-point plan to use the law to protect the UK's dark skies and night-time landscape is inspired by a national law passed in France in 2019 to prevent, reduce and limit light pollution in outdoor spaces – specifically upward-directed light – and similar regulations in South Korea.

Their plans build on what's being done in national parks and remote places in the UK, to encourage and enable local authorities to crack down on unnecessary light pollution; they need new powers to do so, and that means new legislation.

Among the APPG's targets are outside floodlights, light fittings that angle upwards, and blue-spectrum light that disrupts both astronomers' observations and the diurnal cycles of animals.

Here's a summary of the APPG's 10 policy solutions to mitigate sky glow – and what they mean for our night sky…

The 10-point plan to protect UK dark skies

UPDATE LAWS

1. Strengthen the National Planning Policy Framework
This is where new policies and laws come from, but at present light pollution is overlooked.

2. Expand the scope of the planning permission process
Right light, right place, right time. Advertising boards are regulated for light pollution, but exterior lighting by businesses is not.

3. Strengthen Statutory Nuisance Provisions
'Nuisance lighting' like industrial light glaring through a window is something the 'victim' has to prove. This is about making the perpetrator responsible.

SUPERCHARGE STANDARDS FOR LIGHTING

4. Setting up a Commission for Dark Skies
Efforts to stem light pollution are inconsistent, sporadic and overlapping. This would put all the issues in one place.

5. Standards for brightness and colour temperature
Light bulbs already have information about energy efficiency, so why not add labels about their impact on light pollution?

6. Set standards for lighting direction and density
You can buy a 3,000K floodlight that's dark sky-compliant, but it doesn't come with instructions on how to install it to limit light pollution.

7. Create a 'Dark Sky Hours' code of best practice
Timed public lighting should be extended, should be designed to be less powerful, and also applied to private businesses and homes.

NEW DARK SKY GOVERNANCE

8. Minister for Dark Skies
Efforts to cut light pollution fall under the jurisdiction of various departments. This would put someone in power to oversee policy-making.

9. Dark Sky Towns & Cities
International Dark Sky Reserves and Parks are great, but updating lighting in cities could tackle light pollution.

10. Increase public awareness
Should light pollution be included as a feature in the national curriculum?

MOUSSA81/ISTOCK/GETTY IMAGES

▲ Setting guidelines: Dark Skies Officer Dan Oakley champions less light pollution

What does it mean for stargazers?

If the APPG is successful there will be new legislation, incremental updates to planning laws and more dark sky-friendly LED lights, making the night sky darker in cities as well as in protected areas.

"We're not taking away anyone's lighting and this doesn't need to be controversial, we just want a trade-off between minimum light required and protecting dark skies," says Dan Oakley, Dark Skies Officer at the South Downs National Park Authority and International Dark Sky Reserve. He thinks that, if restricted to 3,000K and targeted correctly, LEDs can reduce light pollution. That's exactly what happened in the South Downs when sodium streetlights swapped to LED.

"We're always going to have light pollution, but there's no reason why we can't create the right legislation, guidance and messaging to rein it in and minimise it," says Oakley. "It's the right time to fix it because we can now buy the right colour LED lights off the shelves: people just need to know they can do that, and point the light in the right places, to do their bit to limit light pollution. It's an easy fix; no one says they want to see fewer stars!"

Jamie Carter is a science and astronomy writer and author of *A Stargazing Program for Beginners: A Pocket Field Guide*

20 YEARS OF WMAP

One mission to map the background radiation of our Universe revolutionised cosmology. Two decades later, **Ezzy Pearson** looks at what we learned from this revolutionary mission

Two decades ago, we knew very little about the state of our Universe. While cosmologists had speculated on everything from its size to what it's filled up with, there were very few hard and fast measurements to back up those theories.

But that changed when the Wilkinson Microwave Anisotropy Probe (WMAP) launched 20 years ago on 30 June 2001. Over the next nine years, it mapped the sky more precisely than ever before, transforming the scientific field of cosmology from a discipline of educated guesswork to one of precision science.

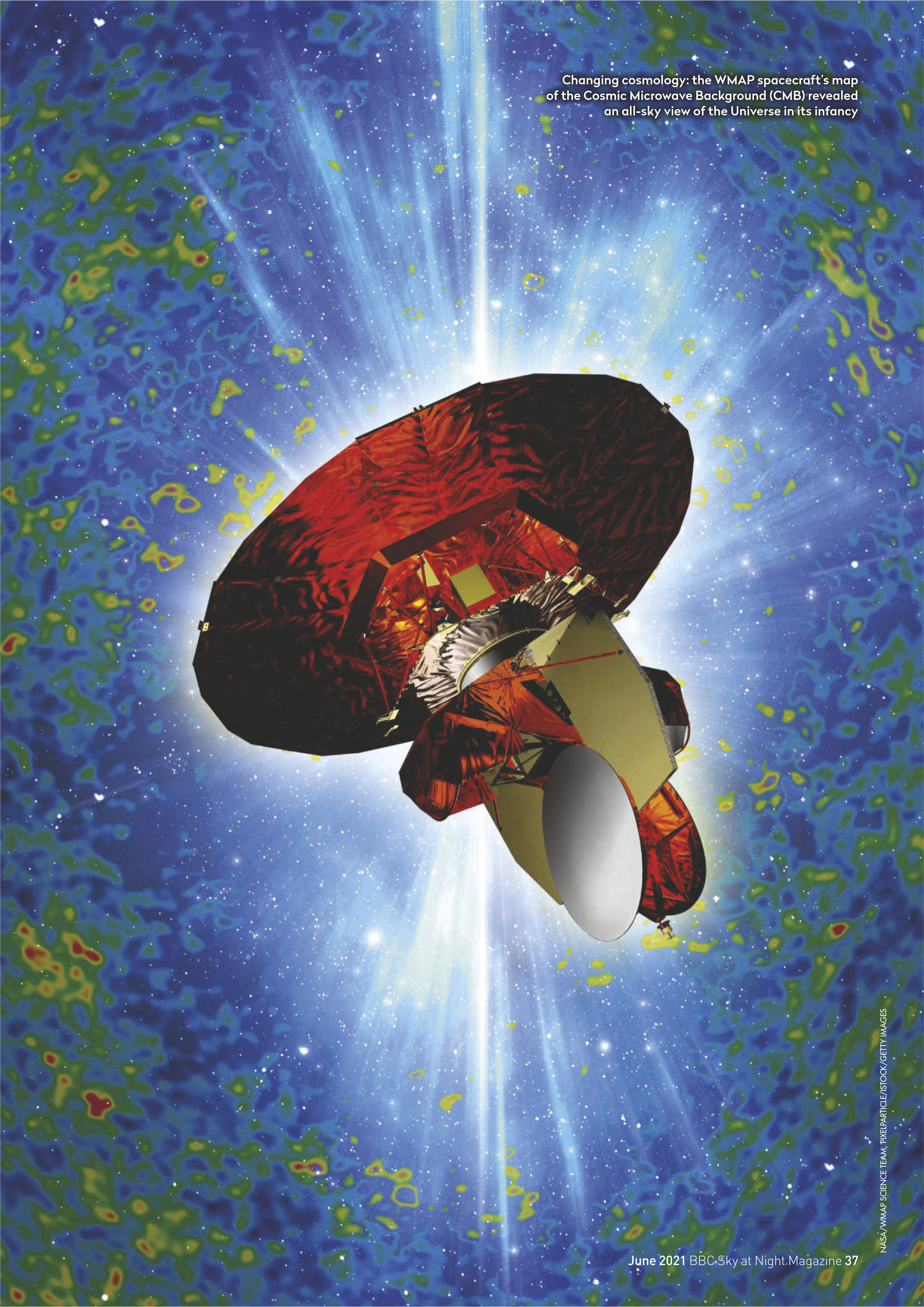
Considering the impact of its results, WMAP was a fairly modest spacecraft. It was proposed in 1995 with a budget of just $150 million, with the goal of creating an all-sky map of the cosmic microwave background (CMB).

But what exactly is the cosmic microwave background? There are few better placed to explain than Chuck Bennett, principal investigator of the WMAP mission. "The CMB is the remnant energy left from the early Universe," he says. "It was high energy radiation, but because the Universe expanded and cooled, its energy dropped into the microwave region of the spectrum. It's basically a photo of the early Universe."

WMAP mapped the sky more precisely than ever before, transforming the field of cosmology into precision science

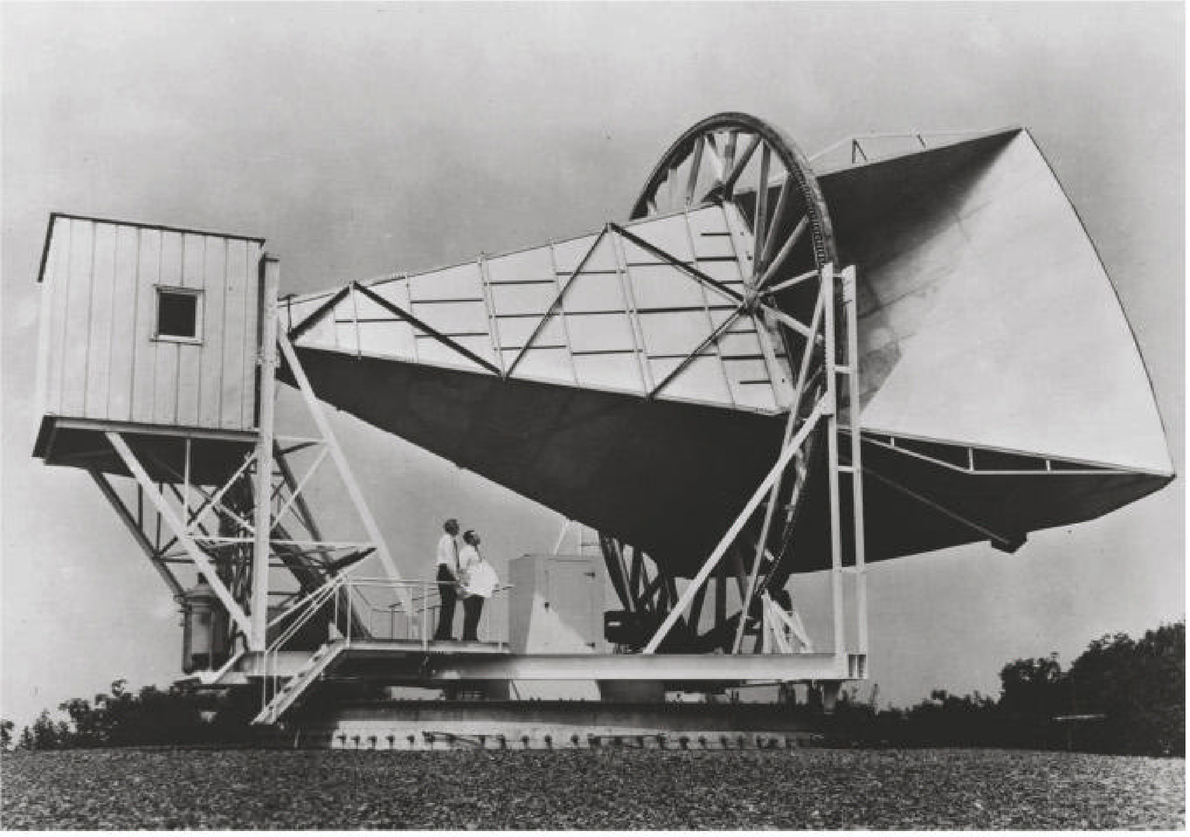
The CMB was first observed in 1964 as a background hiss of microwaves coming from every direction, with a temperature of approximately 4 Kelvin (or 4°C above absolute zero), which would later be measured more precisely as 2.75K.

It took almost 30 years from that initial detection for the first full-sky map of the CMB to be charted by the Cosmic Background Explorer (COBE). Operating between 1989 to 1993, this spacecraft revealed that the CMB's temperature wasn't uniform in all directions, but rose and fell by 0.003K – a change of just 0.1 per cent. Though miniscule, these fluctuations were an imprint of the structure of the Universe at the time the CMB was created, just 378,000 years after ▸



Changing cosmology: the WMAP spacecraft's map of the Cosmic Microwave Background (CMB) revealed an all-sky view of the Universe in its infancy

NASA/WMAP SCIENCE TEAM, PIXELPARTICLE/ISTOCK/GETTY IMAGES



◂ Landmark discovery: the Holmdel Horn Antenna at Bell Labs in New Jersey, USA was used by radio astronomers Arno Penzias and Robert Wilson to discover the CMB in 1964

▸ the Big Bang. By studying these fluctuations, cosmologists have been able to work out a great number of details about the Universe – from how old it is to how much dark matter it contains.

Going into detail

But while COBE was a good start, cosmologists realised that more precision was needed to really pin down these parameters, and so the WMAP mission was put forward. After launching in 2001, WMAP spent its first six months in orbit creating an all-sky map of the CMB. The spacecraft proceeded to scan the entire sky another 17 times over the next nine years, each pass adding more detail and precision.

With this map in hand, cosmologists could then use the map to establish exactly what kind of Universe we live in. Prior to WMAP, cosmologists had been able to use theoretical models, such as relativity and our understanding of the Big Bang, to generate a set of mathematical instructions explaining how the Universe came about. If we think of this as a cake recipe, they knew the method for baking, but what they didn't know was how much of each ingredient there was or how long it had been cooking.

"We have computer programs where we can put in different ingredients – how much dark matter, dark energy – anything we want," says Bennett.

What is the cosmic microwave background?

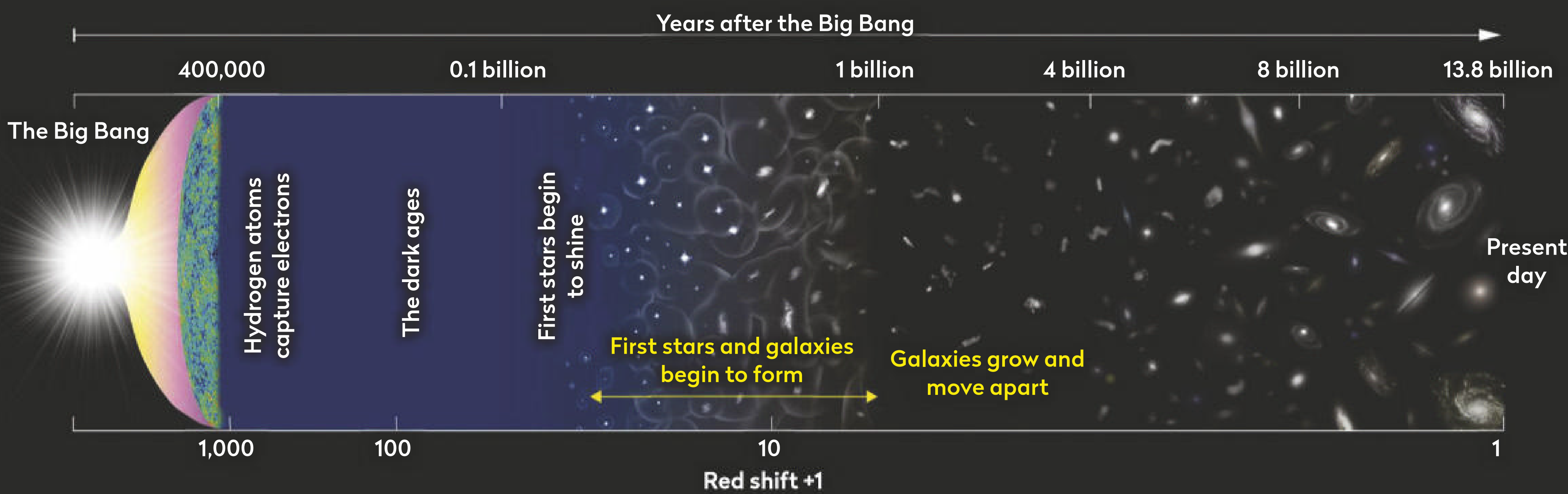
The CMB is the earliest light to have been created in the Universe

When the Universe was formed, it was so hot that hydrogen atoms couldn't hold themselves together. Instead, the cosmos was awash with a hot plasma of electrons floating separate from their protons.

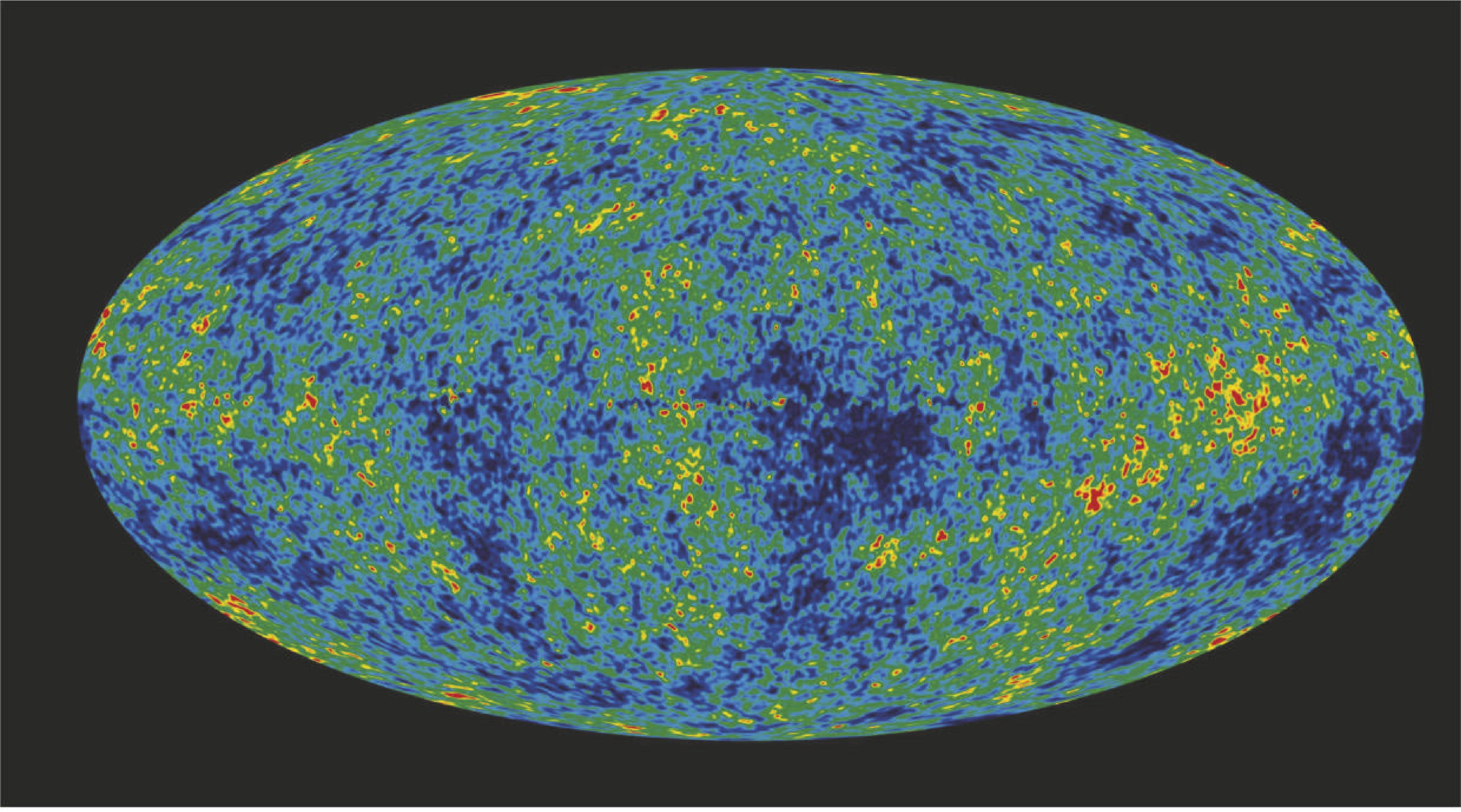
Since free electrons interact and absorb light photons with ease, the earliest light couldn't travel very far. This made the Universe opaque, as if it was filled with a thick fog in all directions.

During this time the Universe was constantly expanding, cooling as it did so, until around 370,000 years ago, the temperature reached around 2,700ºC – cool enough for hydrogen atoms to stay together. The free electrons were captured, and photons were able to travel unimpeded through the Universe.

As these light particles don't disappear until they hit something, many of the photons produced during those early days of the Universe are still around, flying in all directions to create a general haze of radiation. However, the Universe's continual 14 billion years of expansion has stretched out the photons, effectively spreading out the amount of energy they have and reducing them from the bright, visible-light photons they were originally to the microwaves we see today.



▴ A diagram (not to scale) depicting the major milestones in the evolution of the Universe since the Big Bang – around 13.8 billion years ago. The Universe was initially in a neutral state until light from the first stars started to ionise the hydrogen



▲ **Mapping the Universe: over nine years, the WMAP spacecraft added ever more detail to its map of the CMB**

Even small changes to these cosmological parameters – the numbers governing factors such as how much dark matter there is, or how fast the Universe is expanding – results in a very different looking Universe. The only way to create a simulated Universe that looks anything like observed reality is by putting in the correct parameters.

"We run all these cases and try to match the observations," says Bennett.

The 'matched' simulation isn't an exact replica of the WMAP observations, but instead one which has the same set of statistical properties. Even so, by using this method, the cosmologists were able to pin down the parameters to a much higher degree of accuracy than had ever been managed before.

"There was a factor of 70,000 improvement. It was enormous," says Bennett.

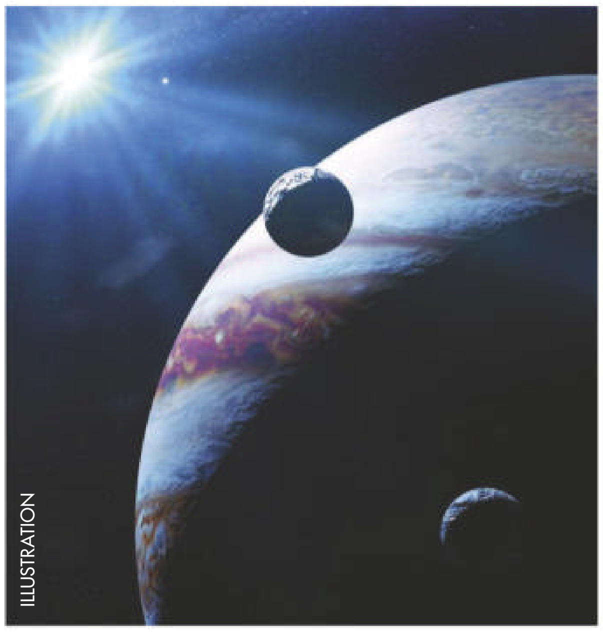
While these parameters might look like a table of random numbers to the uninitiated, to cosmologists it was a revolutionary insight into the long-hidden nature of our Universe.

One of the first things the group tried to pin down was what our Universe is made of. As we understand it, space is filled with three basic things. First is baryonic matter, which is what cosmologists call normal matter – things like the atoms that make up everything from the stars and planets, to you and the magazine sitting in your hands. Then there is cold dark matter, an unseen material that doesn't interact with light, rendering it invisible to conventional telescopes. The only reason we know it's there is because astronomers have tracked the motions of galaxies and deduced there is an invisible mass holding them together. Finally, there is dark energy – a mysterious 'anti-gravity' force, which seems to be driving space apart.

Building blocks of the Universe

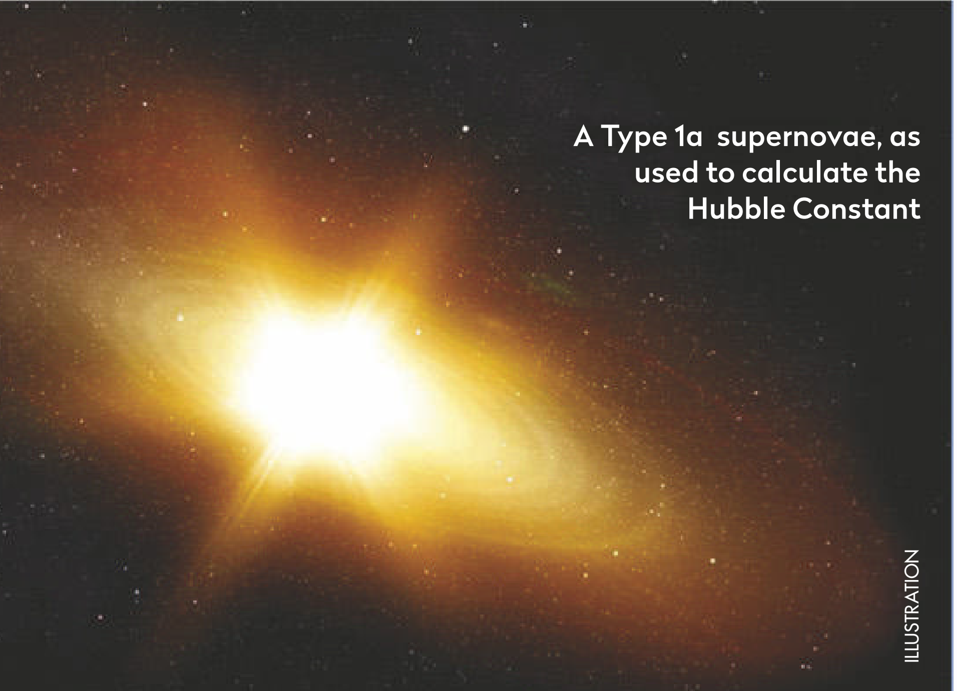
From using WMAP measurements, astronomers could start to calculate the ratio of these three parts.

"We have the make-up of the Universe as five per cent atoms, 25 per cent cold dark matter and 70 per ▸



▲ **Universal matters: three types of matter make up our Universe: stars and planets (left) are made from normal matter; dark matter holds galaxies (middle) together; while dark energy forces them apart (right)**

NAOJ, NASA/WMAP SCIENCE TEAM, DOTTEDHIPPO/ISTOCK/GETTY IMAGES, JOHANNES SCHEDLER/CCDGUIDE.COM, TOMMY NAWRATIL/CCDGUIDE.COM



A Type 1a supernovae, as used to calculate the Hubble Constant

ILLUSTRATION

The Hubble Tension

The expansion rate of our Universe still remains controversial

Though WMAP solved many mysteries, it did create a new problem around a number known as the Hubble Constant – a number that defines the current rate of expansion in the Universe today. Before WMAP, the value was only vaguely estimated to lie somewhere between 50 and 100 km/s/Mpc –that's velocity (kilometres per second) per unit of distance on a galactic scale (Mpc or Megaparsec). After WMAP, the value had been narrowed down to 69.7 km/s/Mpc, with an error margin of less than one per cent.

However, there was a problem. Astronomers measuring the Hubble Constant with a different technique – using Type Ia supernovae in the nearby Universe – came up with a value of 74 km/s/Mpc, with a similar degree of precision. Multiple teams have re-evaluated both numbers and concluded that both are correctly calculated, but they just don't match each other. This issue is known as the Hubble Tension.

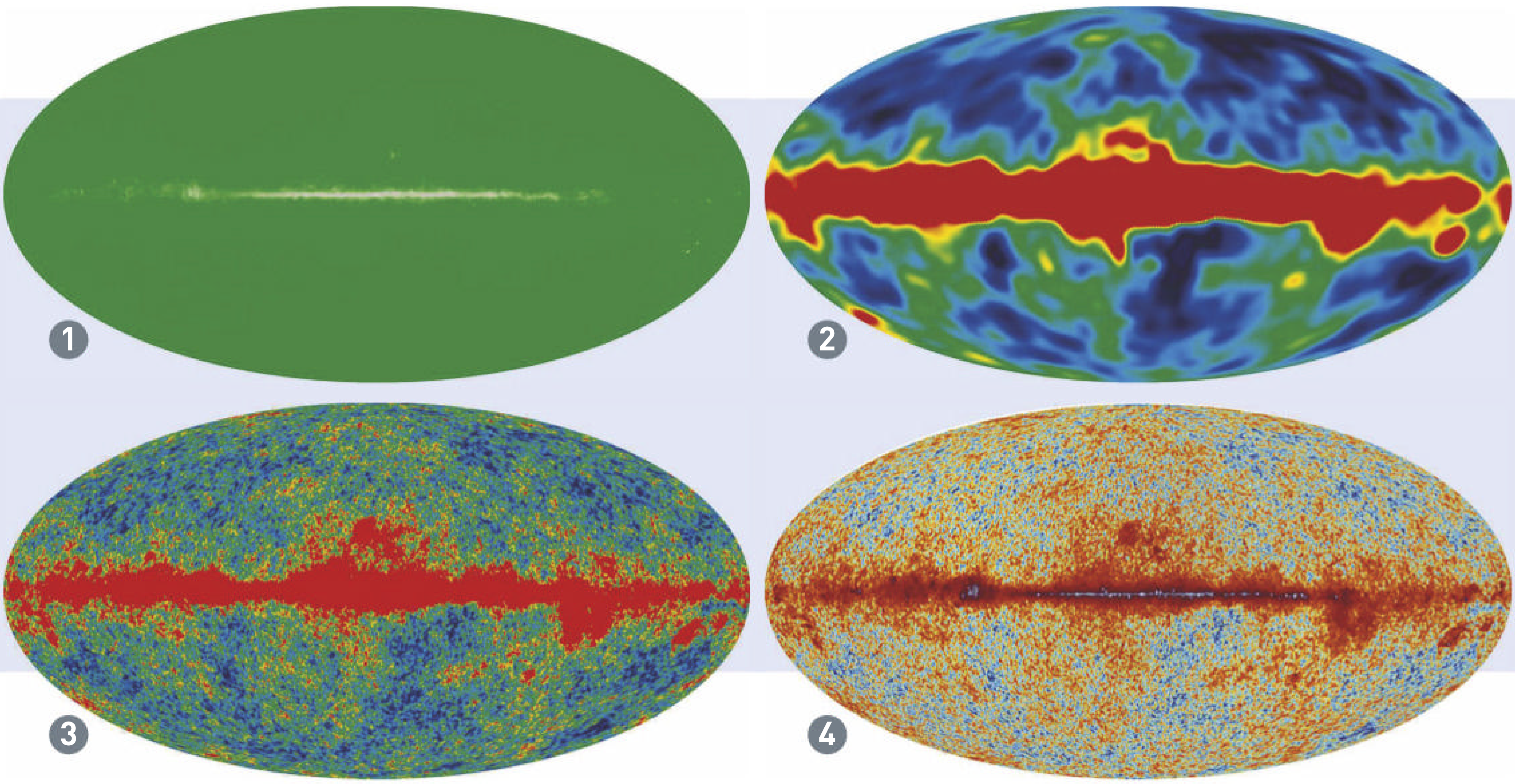
"People are in contention about whether it's an error in the measurements or an error in the theory," says Bennett. "There could be some crazy effect going on that we just don't know about. This is the big picture for me – there can be lots of things we don't know. Do we really understand how light propagates through space? We don't really understand that. Alternatively, there could be some particle out there that doesn't contribute significant energy but interacts with light in some way. It wouldn't surprise me if there's a physical effect we didn't expect."

▸ cent dark energy," says Bennett. "Other things flow from that, such as the age of the Universe."

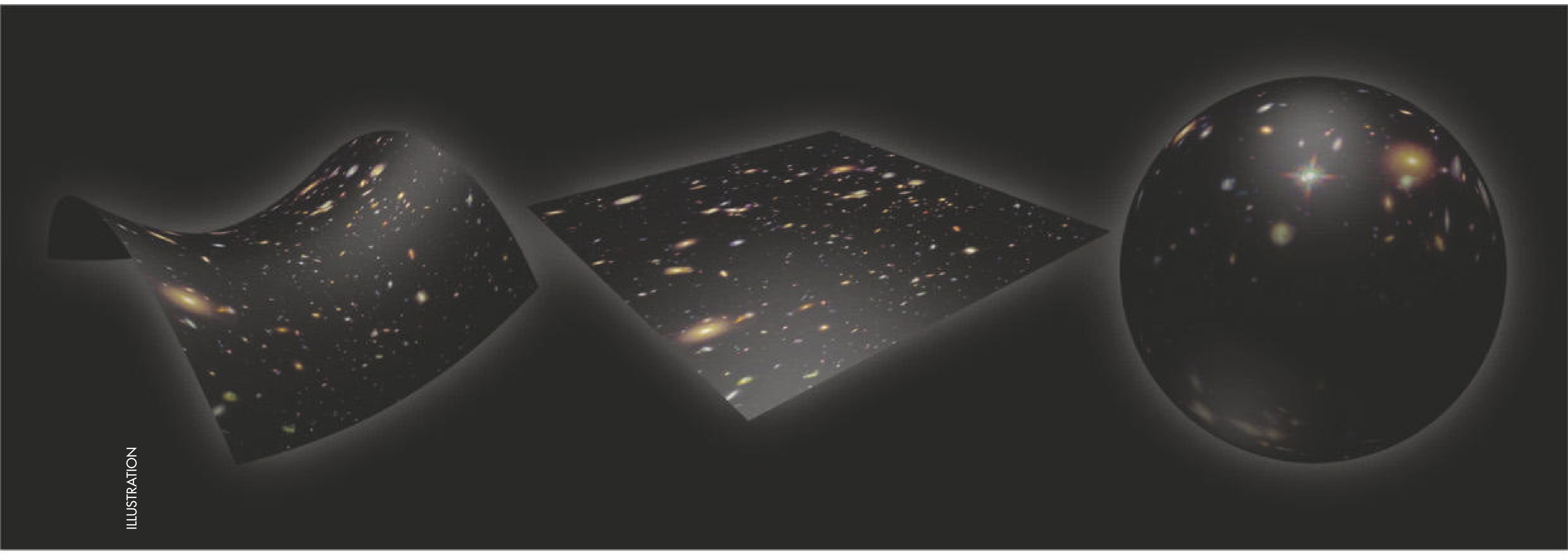
This derives from an extension of relativity, known as the Freidmann equation, which explains how the Universe expands over its lifetime, depending on what it's made of. With these precise compositional measurements in hand, the WMAP team were able to calculate that the Universe is 13.77 billion years old. This same work also helped settle one of the biggest controversies in the field of cosmology at the time – was the expansion of the Universe accelerating?

A question of speed

That expansion was first measured by Edwin Hubble in 1929. Since then, people had been trying to observationally determine exactly how fast the expansion was taking place. In 1998, two separate groups measured that not only was the Universe



▲ How our view of the CMB evolved: 1. The first detection of the CMB in 1964 by the Holmdel Horn Antenna would have looked like this.
2. COBE's view of the CMB in the early 1990s shows a large red band with microwave emissions from our own Galaxy.
3. In 2001, WMAP was able to analyse minute temperature variations, improving detail by a factor of 70,000.
4. ESA's Planck mission used even more sensitive instruments to refine its results, as its 2015 CMB map shows.



▲ **Although various theories suggest that the cosmos could be three different shapes – curved like a saddle (left), flat (middle) or spherical (right), WMAP mapping data has helped cosmologists to favour 'infinite flat geometry'**

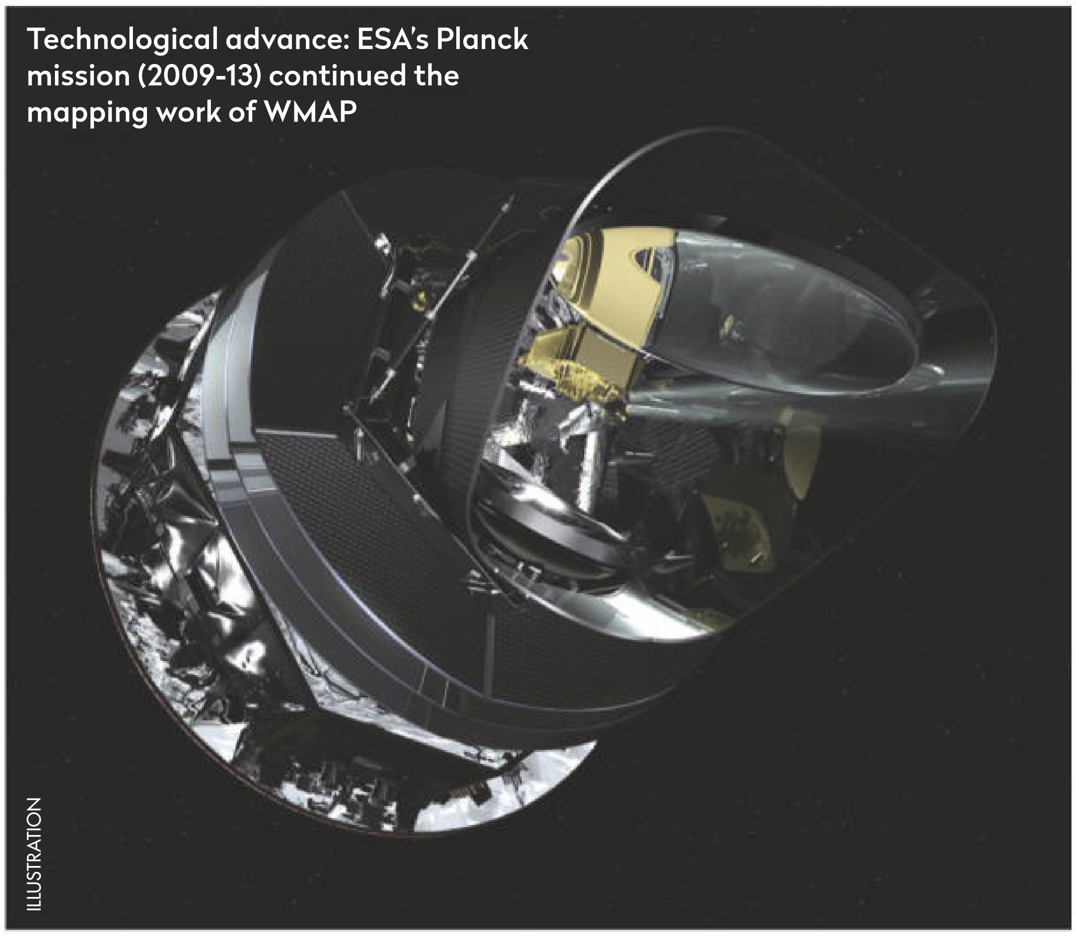
Dr Ezzy Pearson is *BBC Sky at Night Magazine*'s news editor. Her latest book *Robots in Space* has recently been published by The History Press

expanding, but that this rate of expansion was speeding up – the exact opposite of what they expected to find.

"People didn't believe these measurements of the accelerated expansion of the Universe," says Bennett, "Until it was backed up by [WMAP's] independent method of measuring this energy component."

For the expansion to be speeding up, there must be something driving space apart which gets stronger the further things are apart from each other – the opposite of gravity, which pulls things together more strongly the closer they are. To explain this mysterious force, astronomers came up with the concept of dark energy.

"Dark energy is winning the tug of war between gravity pulling things together and the anti-gravity dark energy pushing things apart. The energy component in our model predicts that the Universe will expand forever. However, we still don't know what dark energy is, and if it changes its behaviour in the future, then all bets are off!"



Technological advance: ESA's Planck mission (2009-13) continued the mapping work of WMAP

What shape is the Universe?

One of the final big questions that WMAP helped to answer is what shape our Universe is. The 'curvature of the fabric of spacetime' can be a difficult concept to grasp, requiring you to think in dimensions beyond human perception, so the concept is normally conveyed as a two-dimensional analogy. The Universe could be flat in all directions, with no curvature at all. Alternately, it could be spherical; meaning that like on Earth, though your immediate vicinity might look flat, when you zoom out far enough you can see the Universe is round. Finally, the Universe could be shaped like a saddle, where it curves along one axis in one direction and the opposite way along the other axis.

"What we found was that the Universe is very close to the infinite flat geometry," says Bennett. However, uncertainties in the measurements make it difficult to be sure if the curvature is actually zero, meaning a flat Universe, or if it actually has a slight curve in one direction or the other.

WMAP ended its mission in 2013 having granted humanity a view of the Universe unlike any that had gone before. It was followed by the European Space Agency's Planck mission, which used more sensitive instruments with a much higher resolution to create an even more precise map, which only served to back up WMAP's findings – with the exception of estimating a slightly older age for the Universe, at 13.82 billion years. WMAP was a ground-breaking mission, which completely changed our view of the cosmos. As Adam Riess, a cosmologist who would go on to win the 2011 Nobel Prize in Physics for measuring the acceleration of the Universe once said, "WMAP has brought precision to cosmology and the Universe will never be the same."

GRINDLEY78/ISTOCK/GETTY IMAGES, NASA/WMAP SCIENCE TEAM X 3, ESA AND THE PLANCK COLLABORATION, UNIVERSE SHAPE ILLUSTRATION: PAUL WOOTTON, ESA/ NASA/JPL-CALTECH

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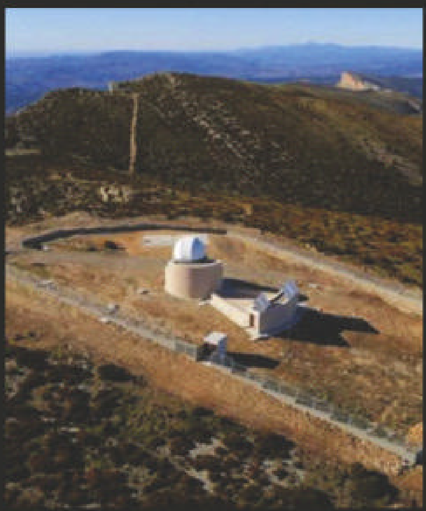

Spain

Perseid Meteor Shower

August 2021

The Perseids are considered the best meteor shower of the year. With very fast and bright meteors, Perseids frequently leave long 'wakes' of light and colour behind them as they streak through the Earth's atmosphere and are also known for their fireballs. Observation is from the Montsec Astronomical Park.

Tour starts in Barcelona, Spain

Antarctica

Total Solar Eclipse

December 2021

We plan to observe this eclipse from a specialist expedition ship, if possible, some distance into the Scotia Sea ice drift. This is a challenging venture with unpredictable weather, ice and sea conditions to battle, but it is one of the world's last great adventures and we can promise a unique experience!

Tour starts in Buenos Aires, Argentina

Australia

Total Solar Eclipse

April 2023

Our main itinerary for this project is based in Perth and features observation from the Exmouth Peninsula. A full programme of tour extensions offers an exciting opportunity to visit other parts of this magnificent country, including Sydney, the Great Barrier Reef and a unique rail journey crossing the entire country.

Tour starts in Perth, Western Australia

Mexico/USA

Total Solar Eclipse

April 2024

Our main observation site in Mexico is near Torreon in Coahuila State. This is a barren desert region, with negligible rainfall in April and the prospects of a clear view of the eclipse are very good. *Extended tour itineraries of the ancient sites of Mexico are also available. Additional observation sites are also offered in Texas and at Niagara Falls.*

Tour starts in Mexico CIty, Mexico

Future Tours

Argentina/Chile	October 2024	Annular Solar Eclipse	Observation from Patagonia or Easter Island
Greenland/Spain	August 2026	Total Solar Eclipse	Observation from East Greenland and locations in Spain
Egypt/Spain	August 2027	Total Solar Eclipse	Observation from various locations in Egypt and Spain
Australia	July 2028	Total Solar Eclipse	Observation from various locations in Australia

Visit our website at www.astro-trails.com to sign up to our newsletter for all project updates

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16-PAGE CENTRE PULLOUT

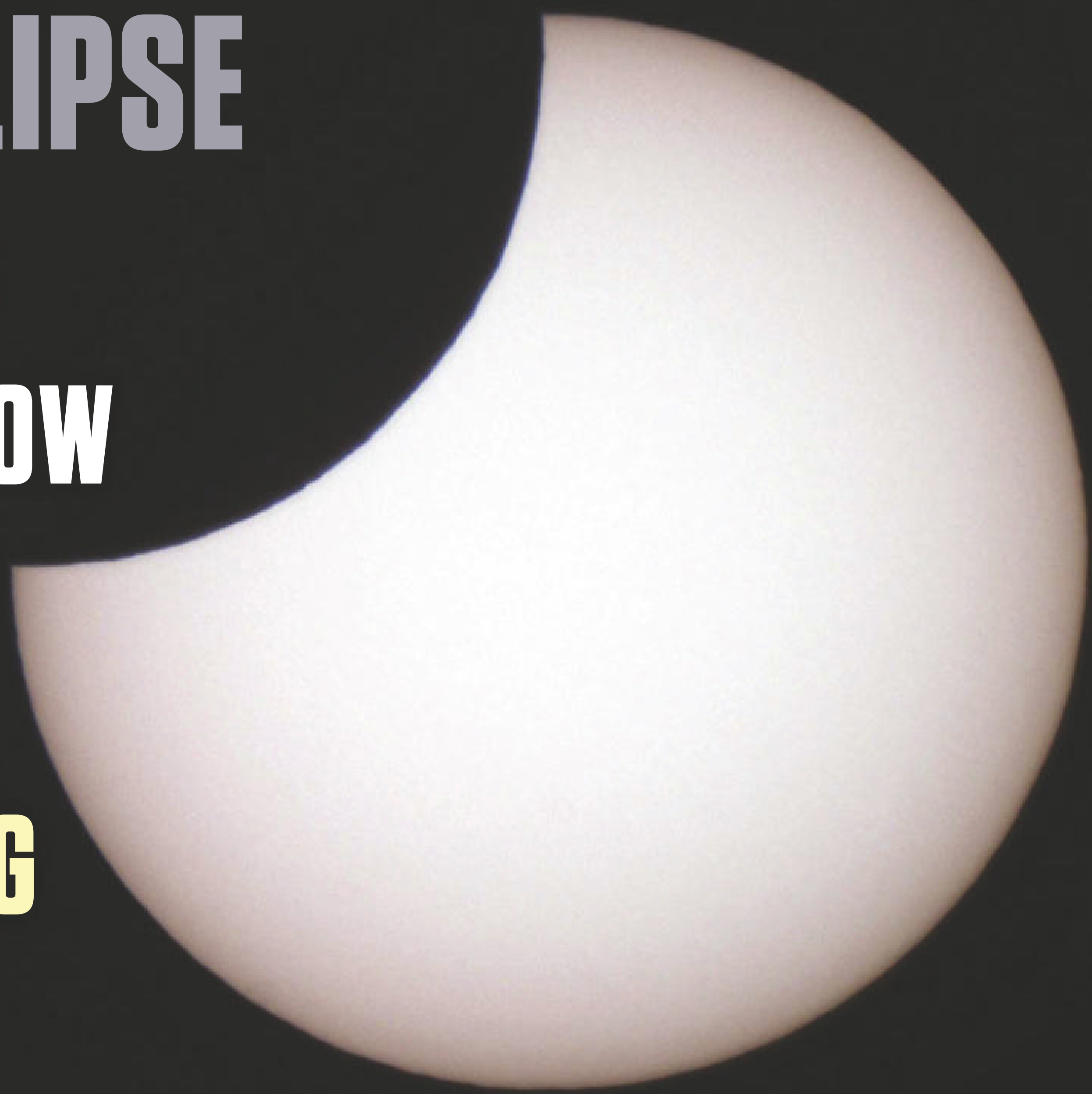
BBC Sky at Night MAGAZINE

The Sky Guide

JUNE 2021

A PARTIAL SOLAR ECLIPSE

Observe the spectacle from the UK on 10 June



PETE LAWRENCE

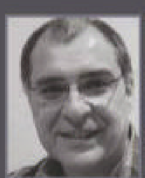
DOUBLE SHADOW TRANSITS

View Jupiter's moon shadows on its disc

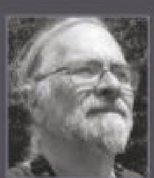
NIGHT-SHINING CLOUDS

The noctilucent cloud season gets underway

About the writers



Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four



Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

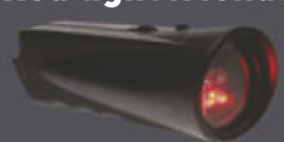
Also on view this month...

✦ Asteroid 30 Urania at opposition

✦ Two clair-obscur effects on the Moon

✦ An evening conjunction of Mars and Venus

Red light friendly



To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

JUNE HIGHLIGHTS

Your guide to the night sky this month

All month

Noctilucent cloud season is upon us and displays of these high-altitude ice clouds may occur at any time. Typically viewing periods are 90–120 minutes after sunset low above the northwest horizon, and a similar time low above the northeast horizon before sunrise.

Tuesday 1

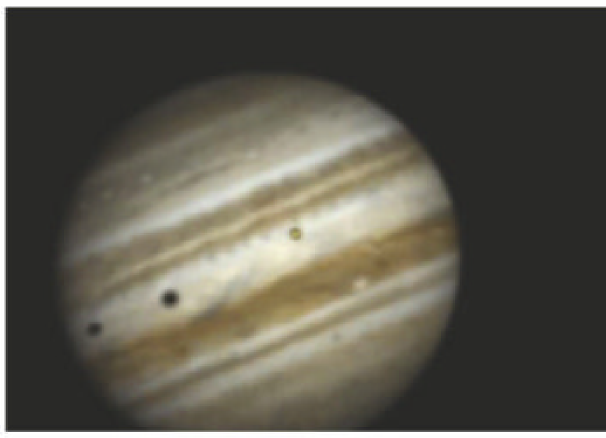
Jupiter will appear close to a 62%-lit waning gibbous Moon in the early hours. The planet is currently shining at mag. –2.3. Look for the pair low above the southeast horizon.

Wednesday 2

A telescopic view of Jupiter this morning will reveal the dark spot of Europa's shadow passing across the planet's disc. The shadow will be centrally located on Jupiter at 02:50 BST (01:50 UT), leaving the disc just after 04:00 BST (03:00 UT) in the dawn twilight.

Saturday 5 ▶

Two shadow transits occur on Jupiter's disc today. As Jupiter rises after 01:30 BST (00:30 UT), Io's and Ganymede's shadows will be concentrically overlaid on its disc. Io's shadow appears to speed off, leaving Ganymede's trailing, to exit the disc at 03:17 BST (02:17 UT).



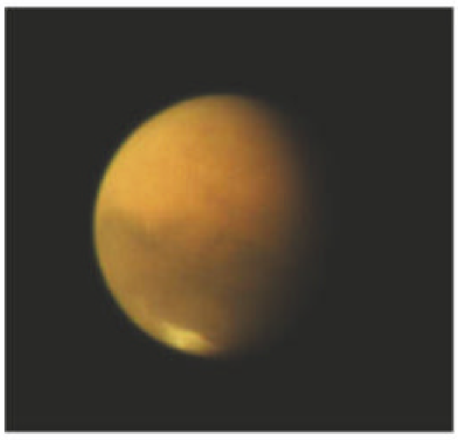
Wednesday 9

A slender 1%-illuminated waning crescent Moon just manages to clear the northeast horizon before sunrise. It's a challenging target requiring a good flat horizon in this direction.

Thursday 10 ▶

Catch Jupiter after it rises (around 01:15 BST (00:15 UT)) to see Callisto in transit. The event ends at 03:30 BST (02:30 UT).

The UK sees a partial solar eclipse in the late morning. See page 46 for more details.



◀ Sunday 13

Mag. +1.8 Mars appears 2° south of a 10%-lit waxing crescent Moon this evening. View from 23:00 BST (22:00 UT) above the west-northwest horizon.

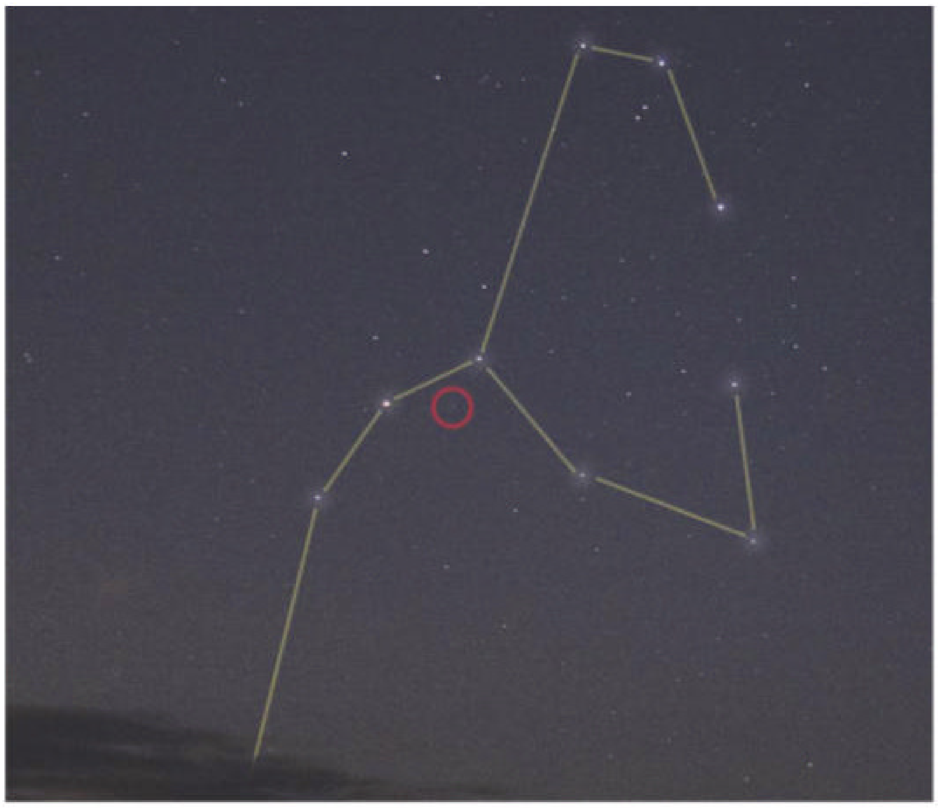
Family stargazing

The solar eclipse on 10 June is exciting but dangerous, especially for those who may not appreciate the risks of looking at the Sun. Therefore, it poses a good opportunity to educate younger family members and to introduce safe ways of viewing the event. One favourite way is to use a piece of stiff card with a 1mm hole in it: cast the shadow of the card onto a white piece of paper and you'll see an image of the Sun and the eclipse. If you fancy getting creative, why not make lots of holes following a shape, or arrange the holes to spell a word. **www.bbc.co.uk/cbeebies/shows/stargazing**

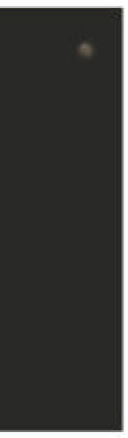
Saturday 26

The shadows of Io and Callisto are in transit this morning. Callisto's shadow starts first from 04:40 BST (03:40 UT), Io's shadow joining in just after 06:00 BST (05:00 UT) under daylight conditions.

PETE LAWRENCE X 8



Thursday ▶
3 Around 01:00 BST (00:00 UT) look for the heart of Scorpius, the Scorpion low to the south. Here you'll find the magnificent globular cluster M4, 1.3° to the west of mag. +1.0 red supergiant Antares (Alpha (α) Scorpii).



Sunday
6 Asteroid 3 Juno reaches opposition today. Located in the constellation of Ophiuchus, the Serpent-bearer, it shines at mag. +10.1.

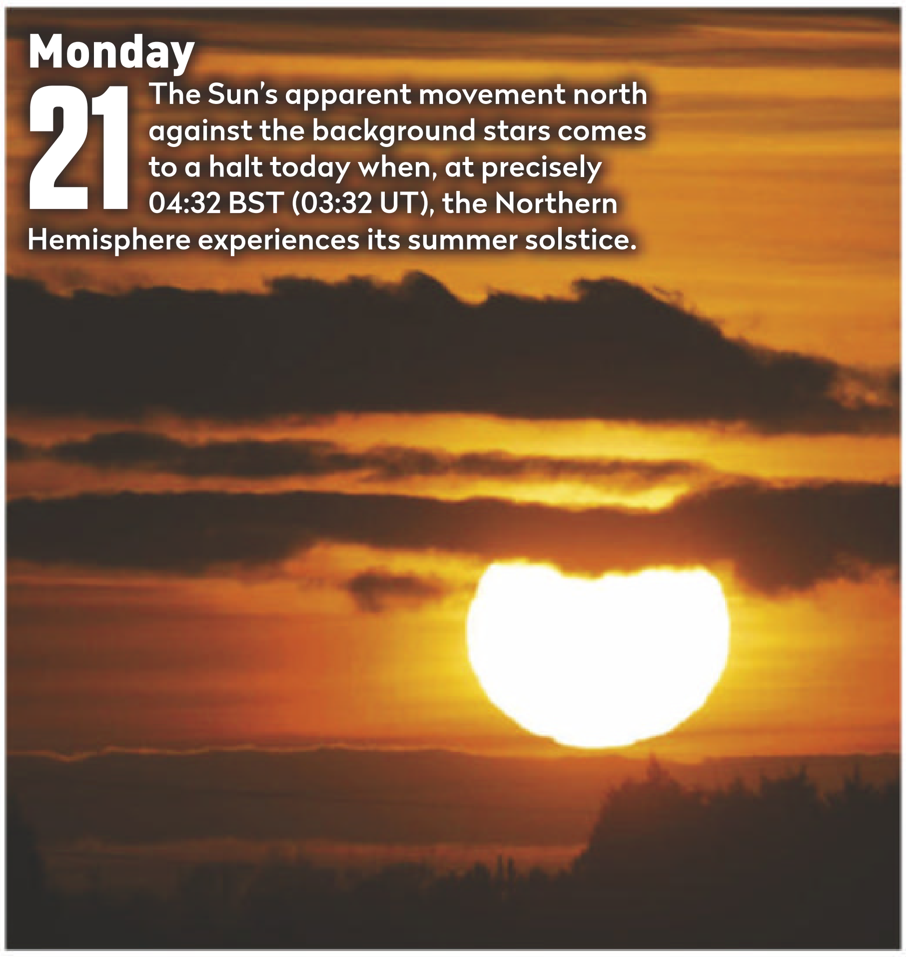
Monday
7 Europa is partially eclipsed by the shadow of Io between 02:36-02:41 BST (01:36-01:41 UT). This is mostly a penumbral eclipse, but a small piece of Europa's northern limb will be properly darkened by the eclipse.

Tuesday
8 The Moon is out of the way, leaving the skies about as dark as they ever get during June. This is the best time to try out our 'Deep-Sky Tour' on page 56.

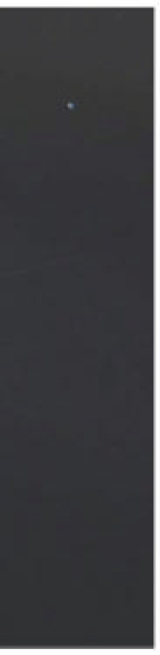
Friday ▶
11 Locate mag. –3.8 Venus low above the northwest horizon 30 minutes after sunset and there will be a delicate 1%-illuminated lunar crescent just under 5° from it, in the direction of where the Sun dips below the horizon.

Saturday
12 Locate the Moon and Venus about 06:30 BST (05:30 UT), about 20 minutes after rising above the northeast horizon, and they'll appear just 42 arcminutes apart. They're visible again later, around 22:30 BST (21:30 UT), near the northwest horizon, 6.3° apart.

Friday
18 Two clair-obscur effects are visible on the Moon tonight. The Eyes of Clavius is visible after 21:00 BST (20:00 UT) and occurs when two inner craterlet rims are illuminated within Clavius. Plato's Hook occurs at 22:30 BST (21:30 UT).



Monday
21 The Sun's apparent movement north against the background stars comes to a halt today when, at precisely 04:32 BST (03:32 UT), the Northern Hemisphere experiences its summer solstice.



◀ Wednesday
30 Mag. –3.8 Venus appears 7.5° west of mag. +1.8 Mars this evening. Look for them above the west-northwest horizon from approximately 23:00 BST (22:00 UT).

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

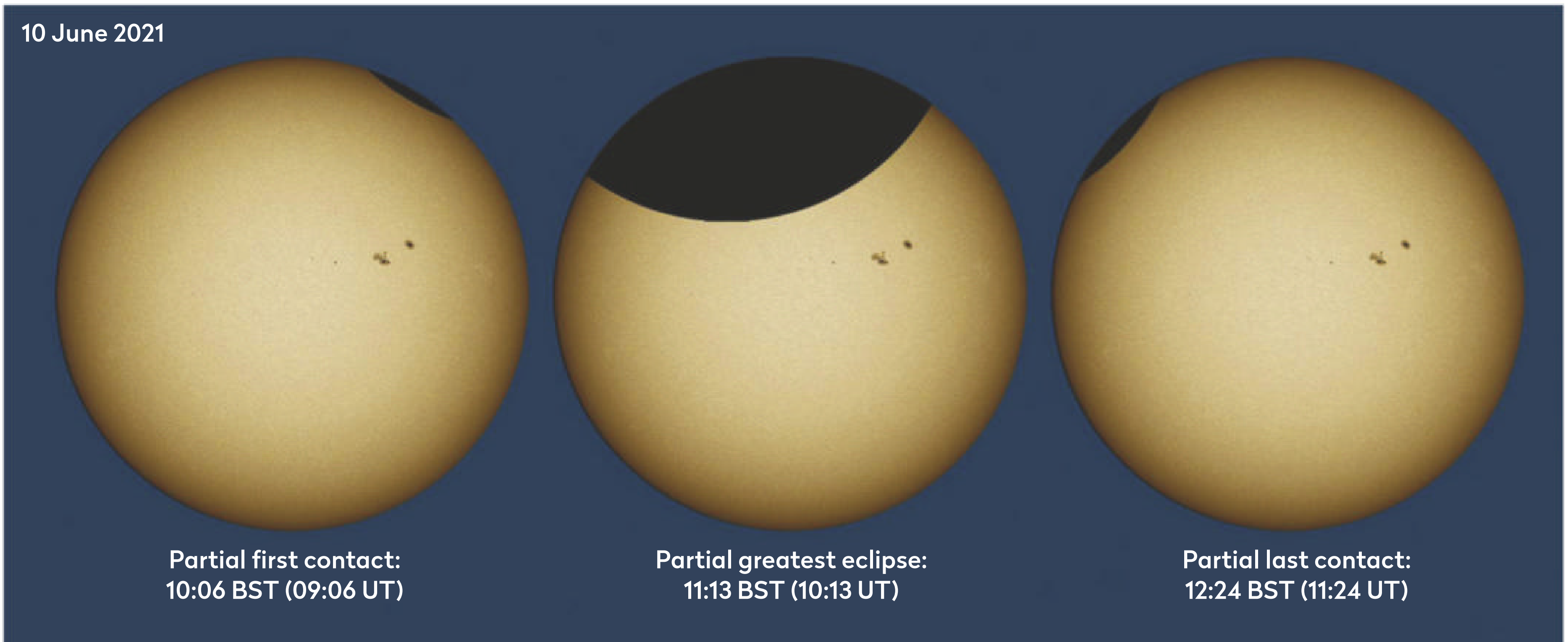
Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY
If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE The three top sights to observe or image this month



The timing and relative positions of the key stages of 10 June's partial solar eclipse. These are correct for the central UK but will vary slightly both in eclipse coverage and timing, depending on location. The first and last contact overlaps are exaggerated for clarity

DON'T MISS

A PARTIAL ECLIPSE OF THE SUN

BEST TIME TO SEE:
10 June from 10:00–12:35 BST

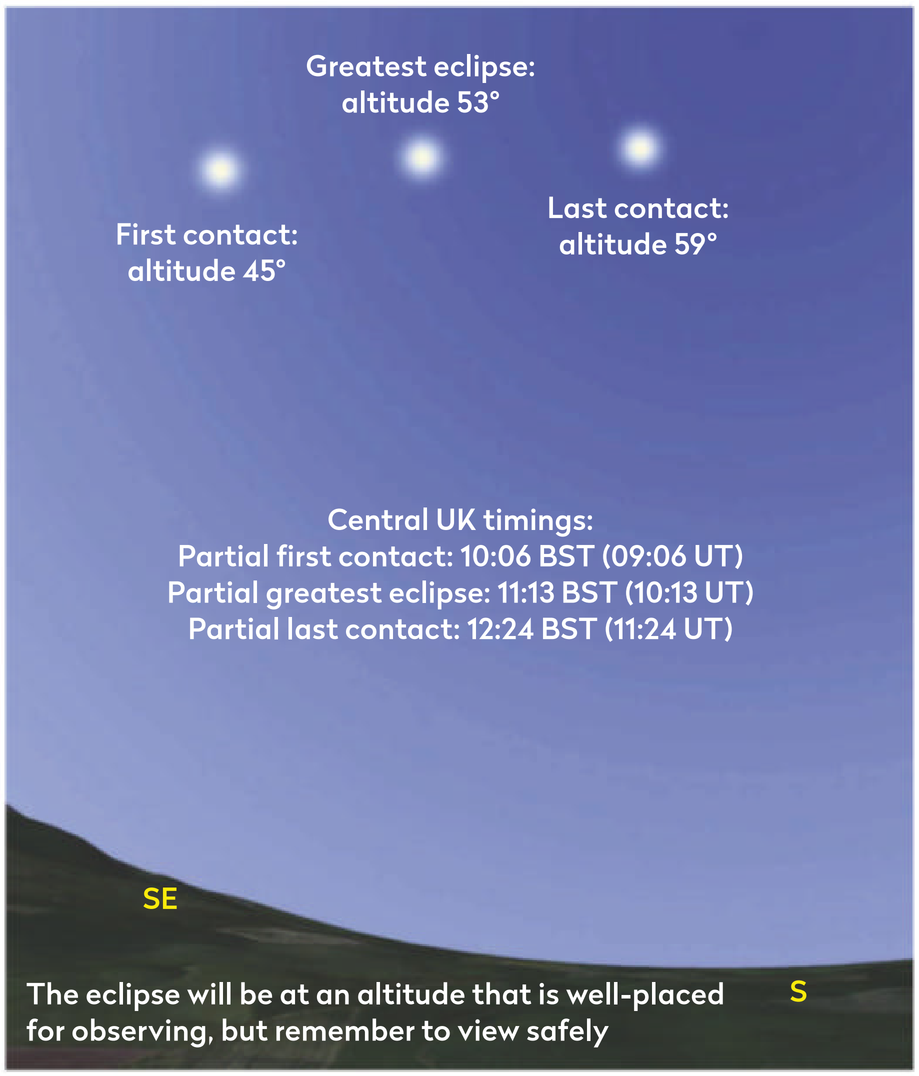
The UK experiences a partial solar eclipse on 10 June, our view of an annular eclipse that's visible across parts of Canada, Greenland and Siberia. From the UK, the event occurs late morning, favouring those living in the northwest. From Birmingham, first contact occurs at 10:06 BST (09:06 UT), with the point of greatest eclipse at 11:13 BST (10:13 UT) when the eclipse magnitude reaches 35.2%; last contact occurs at 12:24 BST (11:24 UT), bringing the event to a close.

Northwest Scotland under clear skies will give the best views. From Lochinver, last contact starts at 10:08 BST (09:08 UT) with a maximum magnitude of 48.8% reached at 11:19 BST (11:35 UT). From Lochinver, last contact is at 12:35 BST (11:35 UT), marking the eclipse's end.

Partial eclipses are defined by one of two values; eclipse magnitude and obscuration.

CAUTION
Never observe or image the Sun with the naked eye or any unfiltered optical instrument

Eclipse magnitude defines how much of the Sun's diameter is covered by the disc of the Moon, while obscuration indicates how much of the Sun's disc area is covered as a percentage. If the Moon's disc encroaches so that its limb reaches the centre of the Sun's disc, this would be described as a magnitude 50% eclipse. Half way across the Sun, the Moon would hide 39.1% of the Sun's area, this being the eclipse's obscuration value. (Birmingham's maximum obscuration is 23.6% and Lochinver's is 36.8%.)



The eclipse will be at an altitude that is well-placed for observing, but remember to view safely

Viewing a partial eclipse is dangerous and getting it wrong could damage your eyesight. For white light-viewing, the use of a solar safety filter such as a Baader AstroSolar film is recommended; and this should cover your scope's aperture. If the film isn't large enough, cover the scope's aperture with card and cut a circular hole in it, over which to fit the filter. If your scope has a secondary mirror central obstruction, make the hole off to one side – an offset aperture mask. Don't forget to cap, filter or remove any attached finderscopes.

▸ **Discover more about the eclipse on page 72, and how to image it on page 76**

ALL PICTURES: PETE LAWRENCE

Jupiter events

BEST TIME TO SEE: 2, 5, 7, 10, 12 and 26 June at specified times

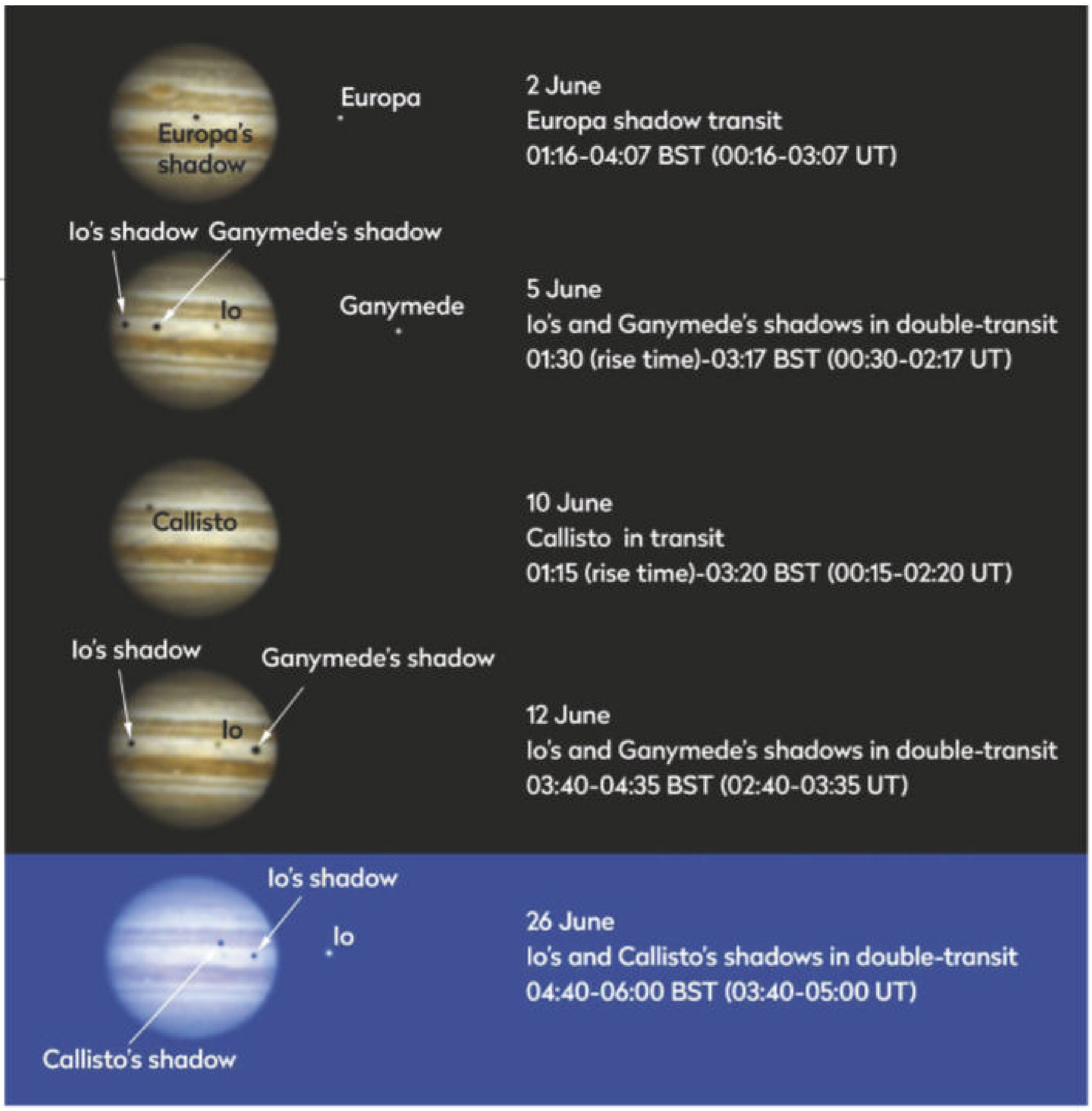
As Jupiter moves into a more night time-friendly position in the sky, we are able to look out for some interesting effects caused by the planet's four largest and brightest moons; the so-called Galilean moons, Io, Europa, Ganymede and Callisto.

Let's start with a naked-eye event involving our own Moon. On 1 June, a 62%-lit waning gibbous Moon lies close to Jupiter in the early hours. On 2 June you'll need a telescope to spot the shadow of Europa passing across the planet's disc. The shadow is centrally located at 02:50 BST (01:50 UT), leaving the disc just after 04:00 BST (03:00 UT) as the dawn twilight is brightening.

On 5 June, the shadows of Io and Ganymede will be coincident on Jupiter's disc as the planet rises, just after 01:30 BST (00:30 UT). Io's shadow then speeds away from the slower Ganymede shadow, exiting the disc at 03:17 BST (02:17 UT).

On 7 June, Europa will be partially eclipsed by the shadow of Io between 02:36–02:41 BST (01:36–01:41 UT), a mostly penumbral eclipse, which should result in Europa's northern limb becoming darkened for a short time.

Then on 10 June, Callisto is transiting Jupiter's disc as the planet rises at approximately 01:15 BST (00:15 UT). Callisto remains in transit until 03:20 BST (02:20 UT). On 12 June between 03:40 BST (02:40 UT) and 04:35 BST (03:35 UT), it's Ganymede's and Io's shadows in transit together once again, while on 26 June, Io's and Callisto's shadows are both in transit together from 04:40 BST (03:40 UT) until 06:00 BST (05:00 UT). The latter event is particularly challenging as it occurs under daylight conditions. The best way to see this is to locate Jupiter earlier using a telescope and stay with it as the Sun rises.



▲ **Moon dance: look out for shadow transits cast by Jupiter's Galilean moons**

Noctilucent cloud season – part 1

BEST TIME TO SEE: All month

June and July are the months of the year in which mid-northern latitudes may experience the phenomenon known as noctilucent or 'night-shining' clouds. These are rare ice clouds that form in a thin layer within the mesosphere at a height of 82km. This thin layer of tiny ice crystals reflects the Sun's light, but the effect is only visible when a balance is struck between a dark, twilight sky and the Sun's altitude being 6-16˚ below the horizon.

As a consequence, the observing windows for noctilucent clouds (NLCs) are typically 90–120 minutes after sunset, when they may appear low above the northwest horizon, or a similar time prior to sunrise when they may appear low above the northeast horizon. Now while these values typically apply, it's worth bearing in mind that NLCs don't always play by the rules. In 2020, evening displays were seen low above the north and northeast horizons after sunset.

Picture perfect: noctilucent clouds make excellent photographic targets

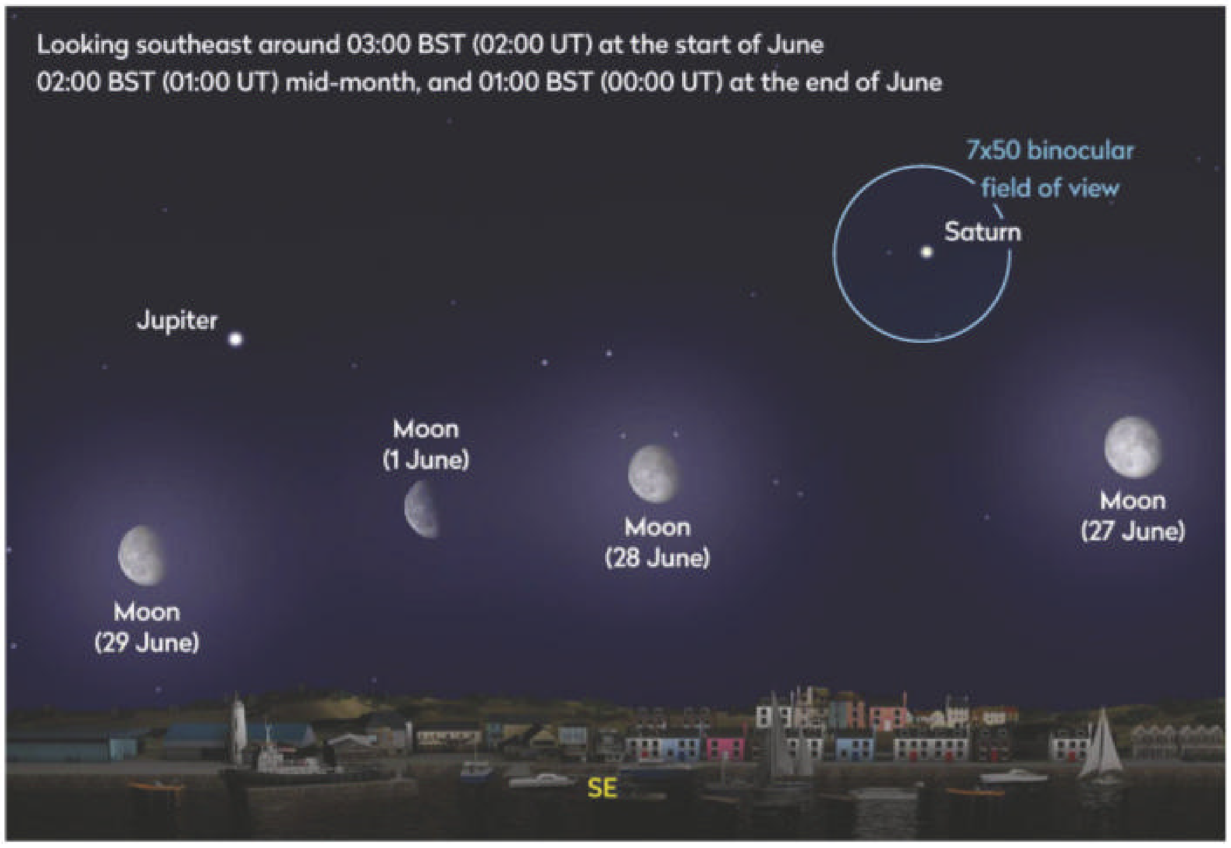
If visible, NLCs typically appear bright, thin and with a network-like wispiness. They often show an electric blue colour and glow against the dark twilight sky. The displays are often extensive and best seen with the naked eye. NLCs also make excellent photographic targets, being suitable for sophisticated DSLRs, MILCs (Mirrorless interchangeable lens cameras) and smartphone cameras.

THE PLANETS Our celestial neighbourhood in June

PICK OF THE MONTH

Saturn

Best time to see: 30 June, from 02:45 BST (01:45 UT)
Altitude: 18˚
Location: Capricornus
Direction: South
Features: Rings, banded atmosphere, occasional storms, brightest moons
Recommended equipment: 75mm or larger



For what seems to have been a long time, Saturn has been appearing very low in UK skies. The reason for this was because it was moving along the most southerly part of the ecliptic. Passing through the constellations of Ophiuchus, the Serpent-bearer and Sagittarius, the Archer, Saturn has been low down and difficult to view.

During 2021, things are slowly beginning to improve. Now in Capricornus, the Sea Goat, it is able to reach a peak altitude of 19˚ as seen from the centre of the UK, not brilliant but definitely an improvement over the 14˚ peak altitude of 2018!

The planet reaches opposition on 2 August and during June is almost able to reach its peak altitude in what passes for a dark sky at this time of year. On 27 June a bright 92%-lit waning gibbous Moon sits southwest of the planet in the dawn twilight. On 28 June, now showing an 85%-lit waning gibbous phase, the Moon sits over to the east-southeast and forms a squat, down-pointing triangle with Jupiter and Saturn.

Low altitude isn't ideal for getting a decent telescopic view of a planet. Low down, you are looking through a thicker layer of atmosphere. Unsteady at the best of times, a thicker layer just increases the amount of wobbly air you need to look through.

▲ Look out for the Cassini Division, the gap between Saturn's A and B rings

If you are lucky enough to get a steady view, the planet's rings are currently nicely on view. Saturn's northern pole is currently tipped towards Earth by 17˚.

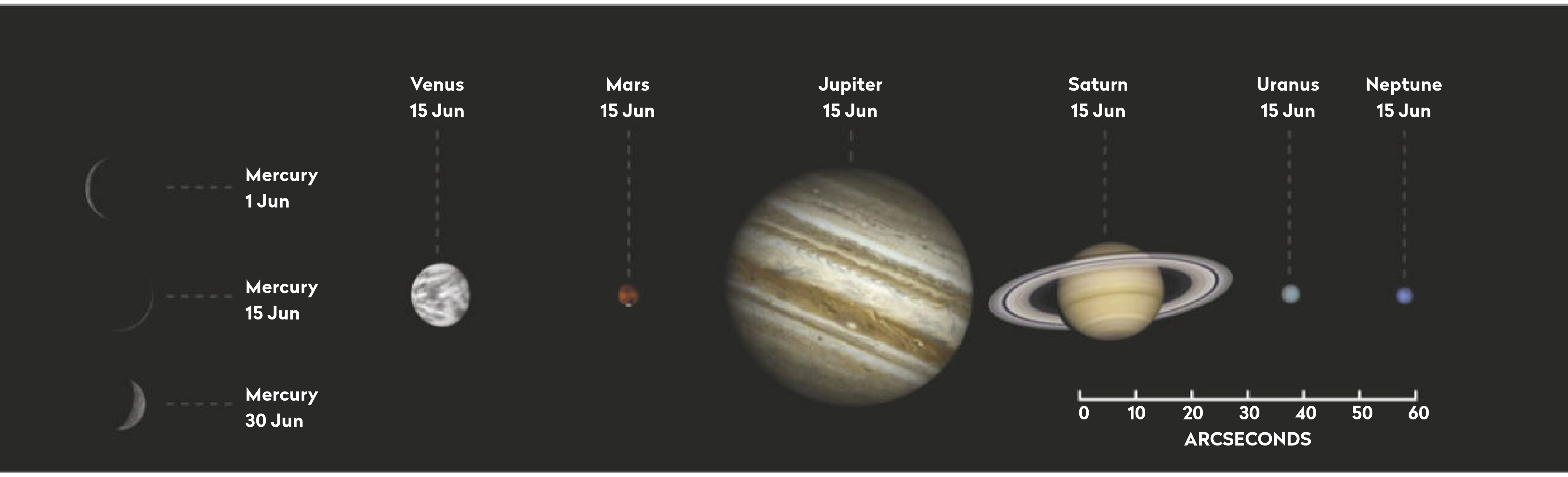
Telescopically, look out for the shadow of the planet's globe on the rings – currently easiest to see to the west of the globe.

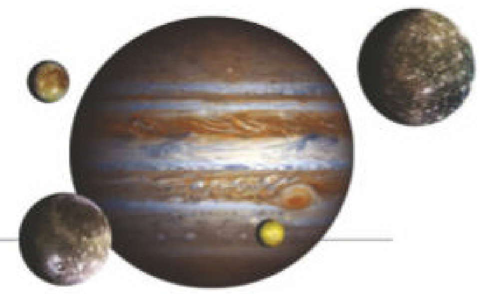
Also look out for the razor thin dark 'gap' between the bright A and B rings. This is the Cassini Division, its visibility being a good indicator of steady conditions.

PETE LAWRENCE X 3

The planets in June

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 30 June, 40 minutes before sunrise
Altitude: 1° (extremely low)
Location: Taurus
Direction: East-northeast
This month we find Mercury in the evening sky, heading back towards the Sun for inferior conjunction, which occurs on 11 June. This follows an excellent period of evening visibility for this tricky planet last month. On 1 June, Mercury sets one hour after the Sun, but is dim at mag. +3.2. This will make it hard to spot against the bright evening twilight. After inferior conjunction on the 11th, it returns to the morning sky but is poorly positioned. On 30 June, at mag. +1.1, the planet rises approximately an hour before the Sun, but visibility is compromised by low altitude.

Venus

Best time to see: 30 June, from 30 minutes after sunset
Altitude: 7° (low)
Location: Cancer
Direction: West-northwest
Venus is an evening planet, setting 1.5 hours after the Sun on 1 June, a time that doesn't vary much over the month. The Moon lies nearby on the 11th as a thin 1%-lit waxing crescent and on the 12th as a 5%-lit waxing crescent. The biggest issue with viewing the planet is low altitude after sunset.

Mars

Best time to see: 1 June, from 22:45 BST (21:45 UT)
Altitude: 13°
Location: Gemini
Direction: West-northwest
Mars is now too small for serious telescopic observation, the planet appearing just 3.9 arcseconds across at the end of the month. Mars cannot be seen against a dark sky this month and at mag. +1.8 will be tricky to spot against a bright June evening twilight. An 11%-lit waxing crescent Moon passes 2° north of Mars on 13 June.

Jupiter

Best time to see: 30 June, from 04:00 BST (03:00 UT)
Altitude: 15°
Location: Aquarius
Direction: Southeast
Jupiter rises three hours before the Sun at June's start, attaining a maximum height of 20° above the south-southeast horizon as the Sun rises. A 62%-lit waning gibbous Moon sits southwest of Jupiter on the morning of the 1st and, with a 76%-lit waning gibbous phase, to the southeast of the planet on 29 June. Jupiter rises five hours before the Sun by the month's end when it's possible to observe it close to maximum altitude as it nears its most southerly position in the sky.

Jupiter reached an equinox on 2 May, a time when the planet is sideways on to the Sun. For the next few months its four largest moons, the so-called Galilean moons, can appear to interact in mutual events, and Callisto casts its shadow on Jupiter. As Jupiter is now pulling away from the Sun in the morning sky, it's easier to see some of the better-timed events (see pages 45 and 47).

A Jovian equinox basically flattens the moon's orbital ellipses into an almost straight line. The three inner moons regularly cross Jupiter's disc, but this is not the case for outer Callisto except when near to a Jovian equinox.

Uranus

Not visible this month.

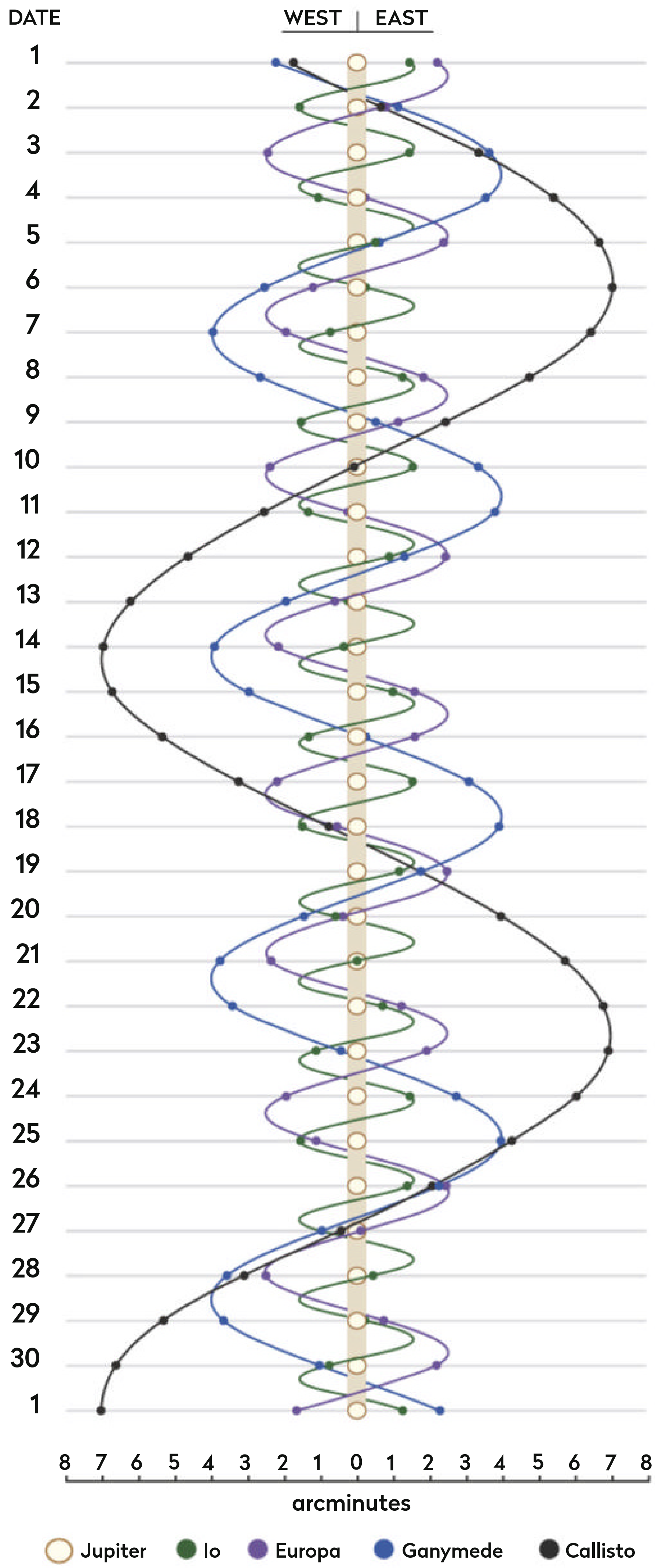
Neptune

Not visible this month.

More **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: JUNE

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – JUNE

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

- N, E, W, S, 5° — COMPASS AND FIELD OF VIEW
- MILKY WAY

CHART: PETE LAWRENCE

When to use this chart

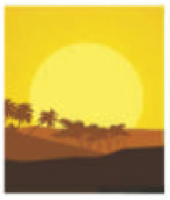
1 June at 01:00 BST
15 June at 00:00 BST
30 June at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in June*



Date	Sunrise	Sunset
1 Jun 2021	04:48 BST	21:29 BST
11 Jun 2021	04:42 BST	21:38 BST
21 Jun 2021	04:41 BST	21:43 BST
01 Jul 2021	04:46 BST	21:42 BST

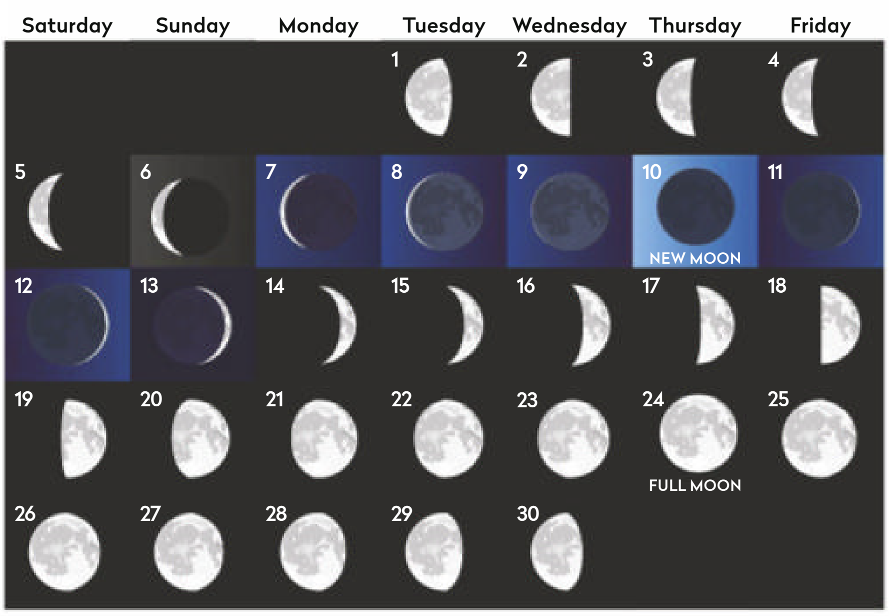
Moonrise in June*

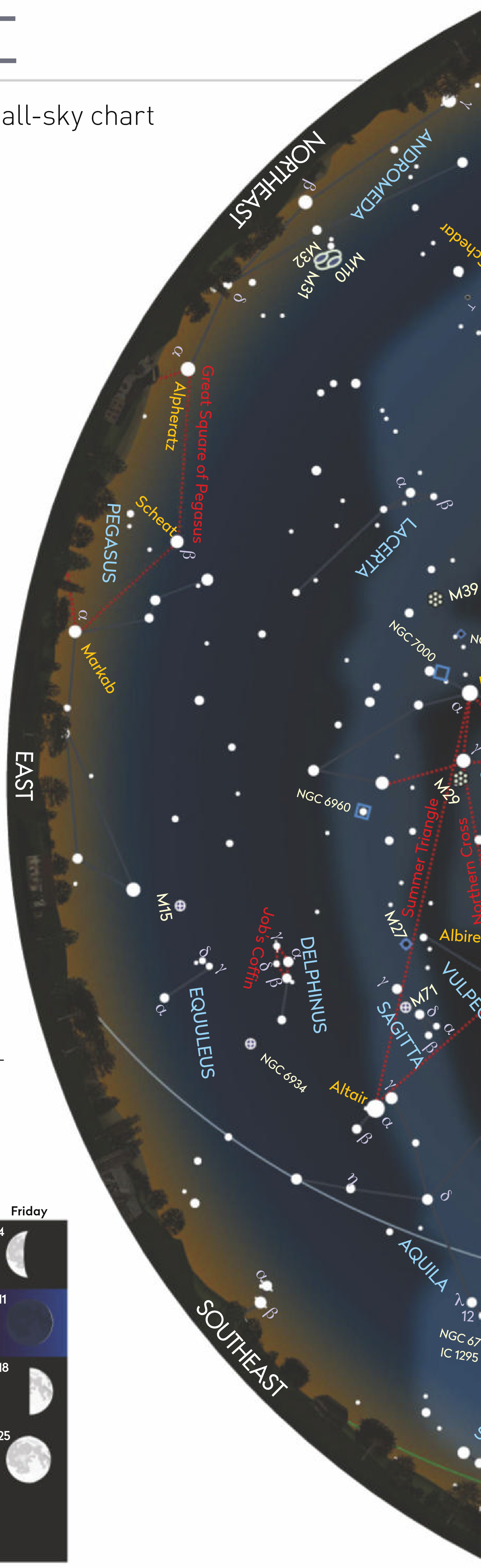
Moonrise times

1 Jun 2021, 02:14 BST	17 Jun 2021, 11:56 BST
5 Jun 2021, 03:09 BST	21 Jun 2021, 17:38 BST
9 Jun 2021, 04:09 BST	25 Jun 2021, 23:02 BST
13 Jun 2021, 06:53 BST	29 Jun 2021, --:-- BST

*Times correct for the centre of the UK

Lunar phases in June





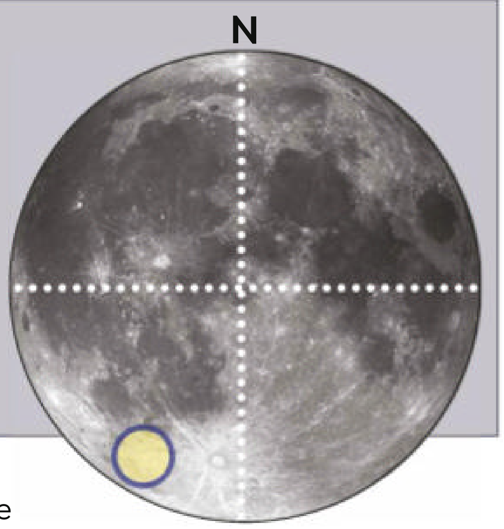
MORE ONLINE

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

Mee

Type: Crater
Size: 133km
Longitude/Latitude: 35.2˚W, 43.6˚S
Age: Older than 3.9 billion years
Best time to see: Three days after first quarter (20 June) or two days after last quarter (5 June)
Minimum equipment: 10x binoculars



Mee is a large crater that is located in the southwest quadrant of the Moon. Its ancient form sits among a hotchpotch of craters of all different shapes and sizes. Mee is over 3.9 billion years old and its boundary has become worn and eroded by smaller impacts, making it quite hard to see under more direct lighting.

There are several ways to locate Mee, depending on whether you're looking at a waxing gibbous or a waning crescent Moon. Let's take the waxing gibbous case first. To begin, identify the distinctive 86km ray crater **Tycho**. This is really easy to find as it's bright and has the largest and most prominent set of bright ejecta rays on the Earth-facing side of the Moon; the rays all converge on the crater. From Tycho, head west for a distance of 200km to arrive at 108km **Wilhelm**.

Wilhelm is a good stop-off point because it too is an ancient formation, estimated to be older than 3.9 billion years. However, it's managed to stave off the ravages of time well and has a good presence on the Moon's surface. Although its rim is heavily cratered, it retains its shape remarkably well. The same is true for 146km **Longomontanus**, located 180km to the south of Wilhelm. Estimated to be older than 3.8 billion years, Longomontanus also retains its shape very well.

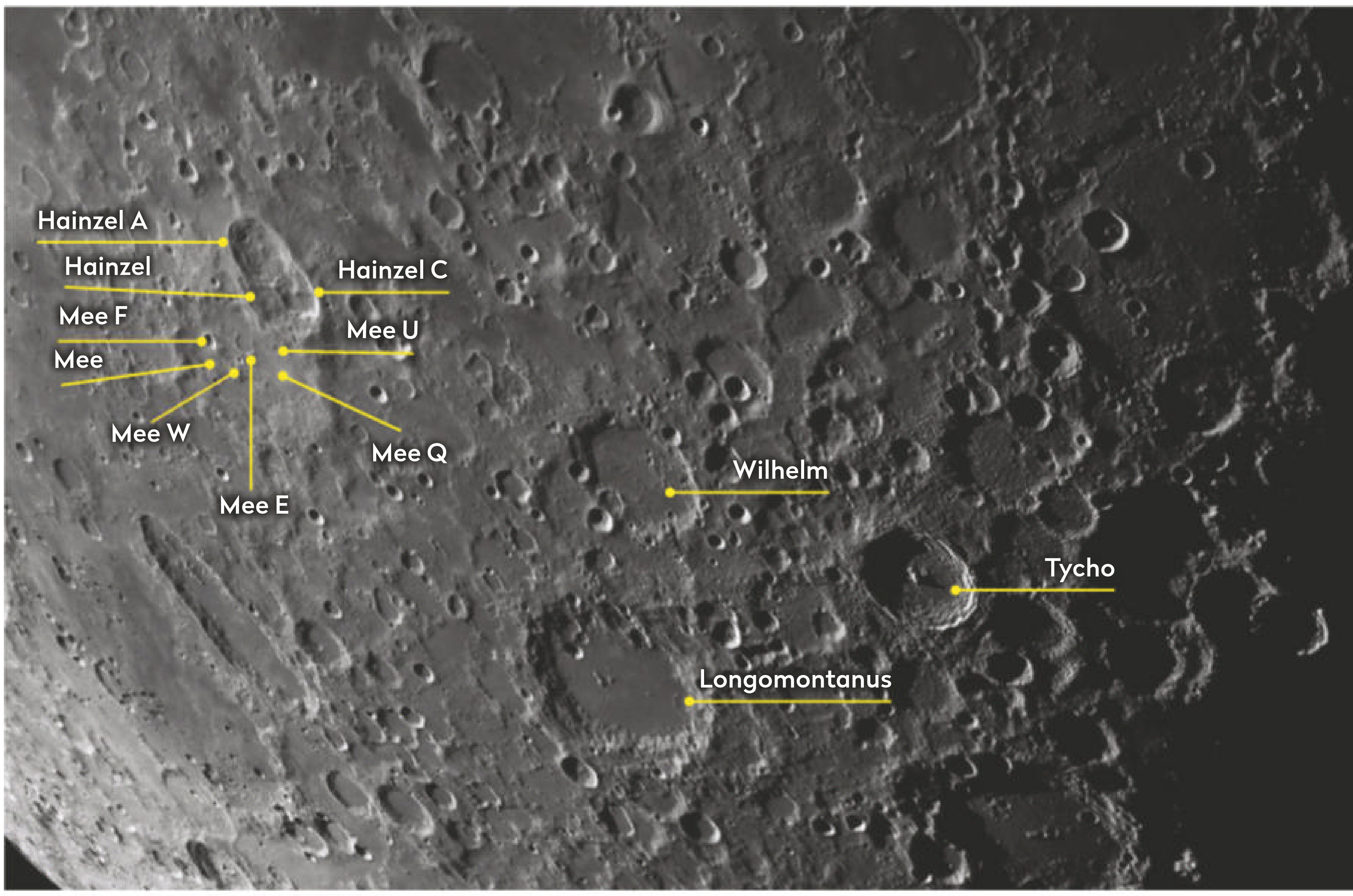
Extend an imaginary line from the centre of Tycho, through the centre of Wilhelm, and keep going for 1.5 times that length again. This will bring you to the floor of Mee and you'll find that the contrast between the craters Mee, Wilhelm and Longomontanus is quite striking.

Mee is best seen under oblique lighting, which tends to give the crater better form. Despite its eroded outline, there's plenty of interest here and the uneven floor contains a number of unusual features. Horseshoe-shaped 16km **Mee E** appears to interrupt what looks like a large, low level region, which may be Mee's central mountain complex. 5km **Mee W** sits close to the centre of this structure with 12km **Mee F** on its western edge. Near the northern boundary is 8km **Mee U**. A tiny craterlet chain, 1km x 5km in size, runs south-north immediately to the west of Mee U. This is a good test of resolution for a large scope or high-resolution imaging setup.

Located near to the eastern edge of Mee is the tiny 1km craterlet **Mee Q**. Despite its diminutive size, Mee Q is easy to see thanks to the ejecta that surrounds it. This contrasts well against the darker floor of Mee. The main diameter of the ejecta pattern is around 6km across, with rays extending for several tens of kilometres.

North of Mee is an interesting triple formation consisting of 70km **Hainzel**, 53km **Hainzel A** and 38km **Hainzel C**. Hainzel A and C appear co-joined into a shape reminiscent of a peanut shell. Hainzel is less obvious, another victim of the ravages of time. It sits beneath Hainzel A and C, completely overlaid by these younger formations.

Mee is over 3.9 billion years old and its boundary has become worn and eroded



▼ **Look for the crater Mee in the Moon's southwest quadrant, where it is surrounded by a hotchpotch of craters**

PETE LAWRENCE X 3

COMETS AND ASTEROIDS

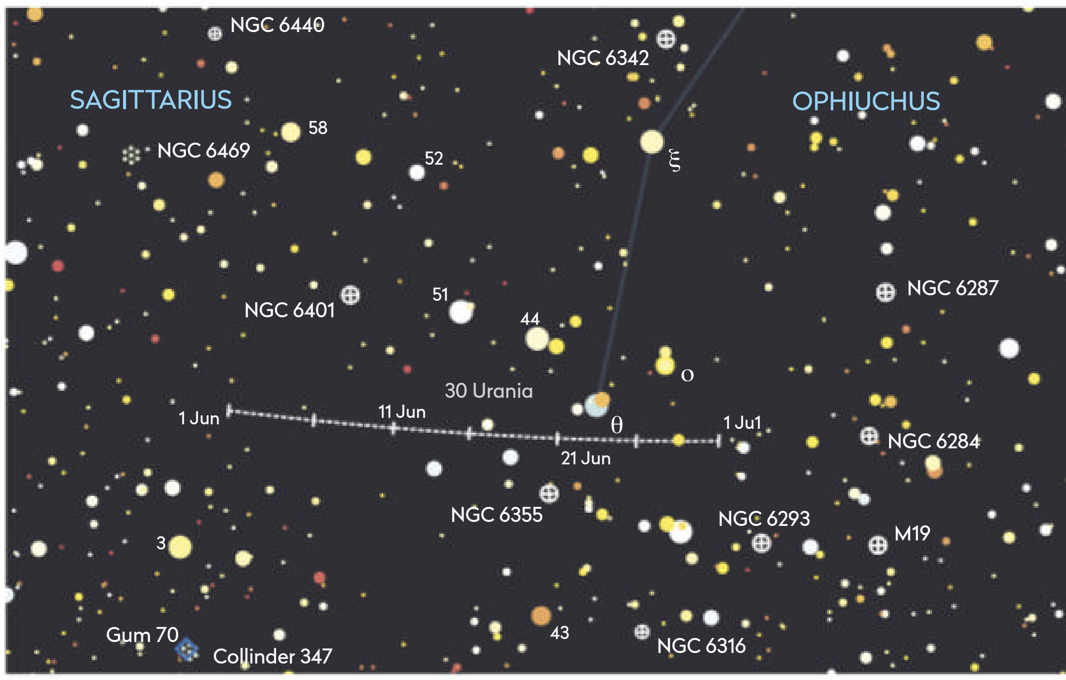
Asteroid 30 Urania reaches opposition in Ophiuchus, the Serpent-bearer

Asteroid 30 Urania reaches opposition on 14 June, when it can be located against the stars of the constellation of Ophiuchus, the Serpent-bearer. Strictly speaking Urania starts the month in Sagittarius, the Archer, 2˚ north of mag. +4.2, 3 Sagittarii. This positions it very close Sagittarius's western border and tracking west, it's not long before Urania crosses this invisible demarcation line, slipping into Ophiuchus in the early hours of 3 June.

Urania remains above or equal to mag. +11.0 all month, a viable target for a small telescope, but beyond average binocular range. Its track this month takes it 2˚ south of the mag. +7.4 globular cluster NGC 6401 on the nights of 6/7, 7/8 and 8/9 June. It passes 0.5° south of mag. +3.3 Theta (θ) Ophiuchi on 22/23 June. By the month's end, it's located 4˚ east-northeast of the mag. +6.8 globular cluster M19. The bright skies found near the June solstice will make locating even a mag. +11.0 object trickier than normal.

Urania is a main belt asteroid. Its shape and dimensions were measured using a technique known as speckle interferometry, which revealed the asteroid to be elliptical with a longest dimension of 111km and narrowest of 89km. At its brightest it can be mag. +9.4, so this opposition doesn't present it at optimal brightness. It takes 3.64 years to orbit the Sun, an orbit that takes it out as far as 2.67 AU and as close as 2.07 AU. Urania is an S-type or siliceous asteroid, a class that has a stony or mineralogical composition. S-type asteroids account for about 17 per cent of asteroids.

30 Urania was discovered by the English astronomer John Russell Hind on 22 July 1854.



▲ **Use a small telescope to track 30 Urania's progress over June**

STAR OF THE MONTH

Anatares, marking the heart of Scorpius

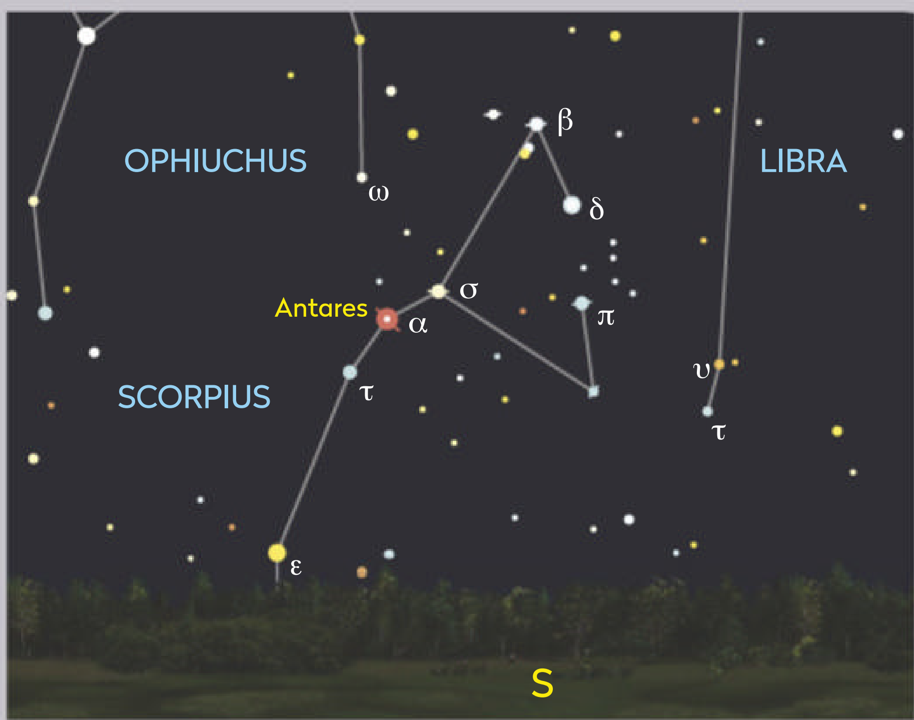
Scorpius is one of the best constellations in the night sky, a large and recognisable depiction of the scorpion that mortally wounded Orion, the Hunter. From the UK, Scorpius is too low to properly appear above our southern horizon in the summer. We get to see the northern portion, the part that includes the creature's heart marked by the orange supergiant Antares (Alpha (α) Scorpii). The 15th brightest star in the night sky, it stands out like a beacon during the darkness-challenged months of June and July, skirting east to west, low above the southern horizon.

Antares has a spectral type M1.5Iab-Ib. 'M1.5' indicates where it sits on the temperature scale, Antares measures 3,387˚C, a cool value that gives the star its orange hue. 'Iab' is the designation of an intermediate-size luminous supergiant, 'Ib' being a less luminous supergiant. Antares is between these designations.

Antares is 550 lightyears away and shines at mag. +1.0, with variability between +0.6 and +1.6. It's about 76,000 times more luminous than our Sun.

The name Antares comes from the visual appearance of the star. Being relatively bright to the naked eye and having an orange hue, it appears similar to how the planet Mars looks to the naked eye. Its name means 'rival to Ares', Ares being the Greek name for Mars, itself referencing the god of war.

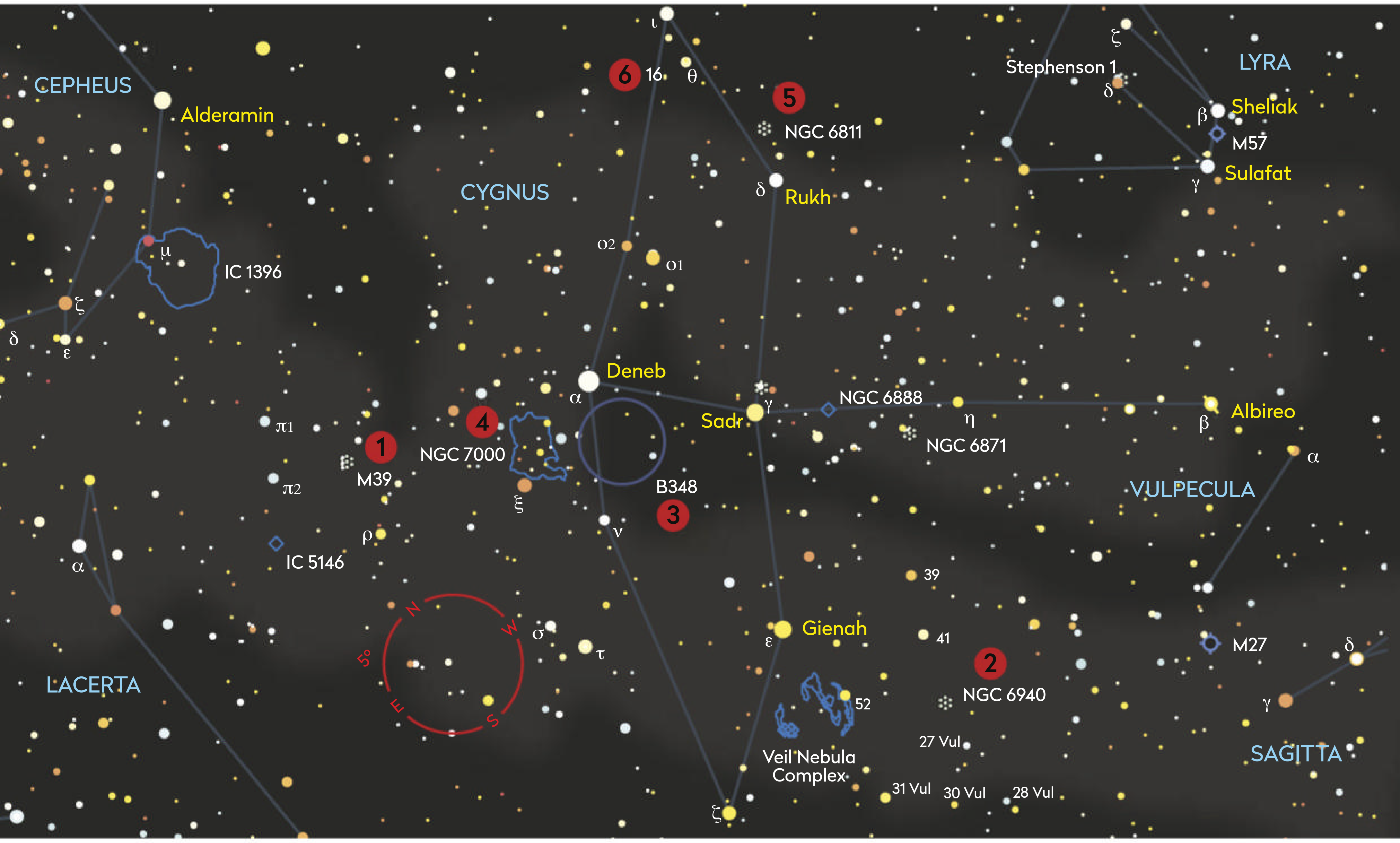
Antares is a binary star, the secondary shining at mag. +5.5 and separated from the primary by 2.6 arcseconds. While its spectral type of B.25V suggests a blue-white colour, its close proximity to orange Antares creates a colour contrast that causes it to appear blue-green.



▼ **To the naked eye, the orange hue of Antares appears like Mars**

BINOCULAR TOUR With Steve Tonkin

Our wide-field destinations include open cluster M39 and the North America Nebula



1. M39

10x50 Given dark adaptation and a decent sky, M39 can be visible to your naked eye; Aristotle described it as "comet-like" in 325 BC. In these conditions, your 10x50s will reveal an equilateral triangle of 15 to 20 stars. However, under brighter skies, you may only see a handful of stars, forming a trapezium as you lose the northern apex of the triangle. This open cluster is 800 lightyears away and spans 7.5 lightyears. ☐ **SEEN IT**

2. NGC 6940

10x50 Use the chart to identify 41 Cygni and 30 Vulpeculae; our next open cluster lies between them. You will find an oval glow that appears to be the about same size as the Moon. As you study this glow, you should be able to resolve eight or more stars, depending on your sky conditions. NGC 6940 is about 2,700 lightyears distant and is thought to be about 800 million years old. ☐ **SEEN IT**

3. The Northern Coalsack

10x50 The Northern Coalsack (B348) is a dark nebula, a region where interstellar gas and dust obscures our view of the Milky Way. You'll find it just east of a line from Deneb (Alpha (α) Cygni) to Sadr (Gamma (γ) Cygni). It has been known since William Herschel's time, when it was thought to be one of several 'holes' in the Milky Way. See how many more 'holes' you can find. ☐ **SEEN IT**

4. The North America Nebula

10x50 The North America Nebula (NGC 7000), is a large bright patch of nebulosity whose centre is about 3.5° east-southeast of Deneb. If you could see M39 with your naked eye, try this as well; it appears as a slightly brighter patch of sky. With binoculars, start by trying to detect the dark nebula that forms the "Gulf of Mexico" (or, if you prefer, "Hudson's Bay"), after which the brighter nebulosity becomes apparent. ☐ **SEEN IT**

5. NGC 6811

15x70 If you put Delta (δ) Cygni near the south-east rim of the field of view of 15x70 binoculars, NGC 6811 is near the middle. It's an unusual-looking open cluster, with a scarcity of stars near the centre, making it appear like a ghostly smoke ring in binoculars. It is nearly 4,000 lightyears away, at which distance its angular diameter of 13.5 arcminutes corresponds to a true size of 16 lightyears. ☐ **SEEN IT**

6. 16 Cygni

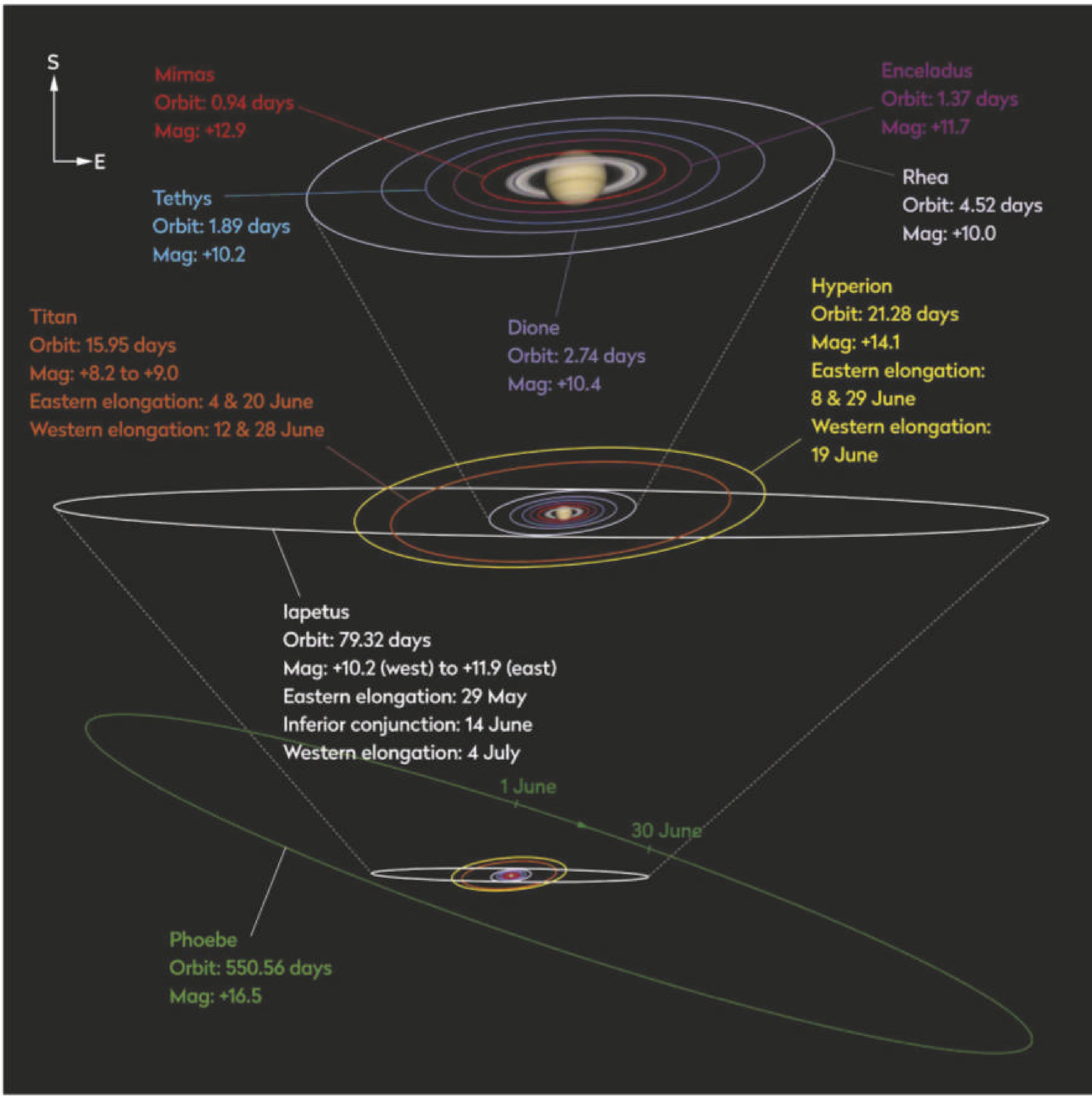
15x70 There is something rather lovely about equal double stars; those whose colour and magnitude are very similar. 16 Cygni is such an example, and it's easy to find, being less than a degree east of Theta (θ) Cygni. The separation is 39 arcseconds, so a magnification of 15x will show you this tiny, off-white, 6th magnitude pair. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

How many of Saturn's moons can you record in a month?



▲ **Begin by locating Saturn's inner moons, before moving on to try for the more tricky outer ones**

Jupiter has a lot of moons, the current tally being 79. However, only four are easy to see through typical amateur telescopes. Saturn too has a healthy moon collection, currently totalling 82. This of course ignores the myriad particles that form the planet's spectacular ring system. Saturn's satellite family is more telescope-friendly with six readily viewable through smaller instruments and potential for a few others. This month's challenge is simply to see how many of Saturn's moons you can see through your own telescope.

Saturn moon-spotting is a relatively easy task. Locate the planet, make sure you understand how the view is orientated, and then check where the moons should be via an app or planetarium program. There are various astronomy phone apps which can do this and on a PC there are several popular free or low cost options. Popular examples to check out are Stellarium and Cartes du Ciel.

It should be fairly easy to tick off the brighter Saturnian moons. Starting with eighth magnitude Titan. Once this has been identified, try for Tethys, Dione and Rhea. These tend to appear around the mag. +9.5 to +10.5 range and wander far enough from the planet to be easy to spot. Inside the orbit of the innermost of this trio are Enceladus and Mimas. At around the mag. +11.5 mark, Enceladus requires a bit more concentration. Mimas is close to 13th magnitude and, due to it having an orbit which keeps it close to the ring system, it can be hard to see or image. Here a good magnification, steady skies and patience is needed. Attempt to grab Mimas when close to an elongation.

Phoebe orbits Saturn in the opposite direction to the other moons

Once you've ticked off the inner moons, it's time to try for some of the more difficult outer ones. Iapetus isn't particularly hard when it's close to western elongation, shining around 10th magnitude. However, thanks to a gravitationally locked orbit and a globe which is half light and half dark, when to the east of the planet Iapetus dims to 12th magnitude.

Hyperion's orbit is smaller than that of Iapetus, but it's a far trickier moon because of low brightness. At around mag. +14.5, you'll either need a large telescope around 400mm diameter or an imaging setup to tick Hyperion off the list.

If you do manage Hyperion, how about Phoebe? This moon is retrograde, meaning it orbits Saturn in the opposite direction to the other moons. Phoebe is dim at mag. +16.5, and here you'll almost certainly need to switch to imaging in order to catch it. A worthy climax to this month's challenge, Phoebe's orbit is also large and inclined, making it difficult to locate.

DEEP-SKY TOUR

Explore the celestial gems in the border region between Serpens Caput, Virgo and Libra

1 M5

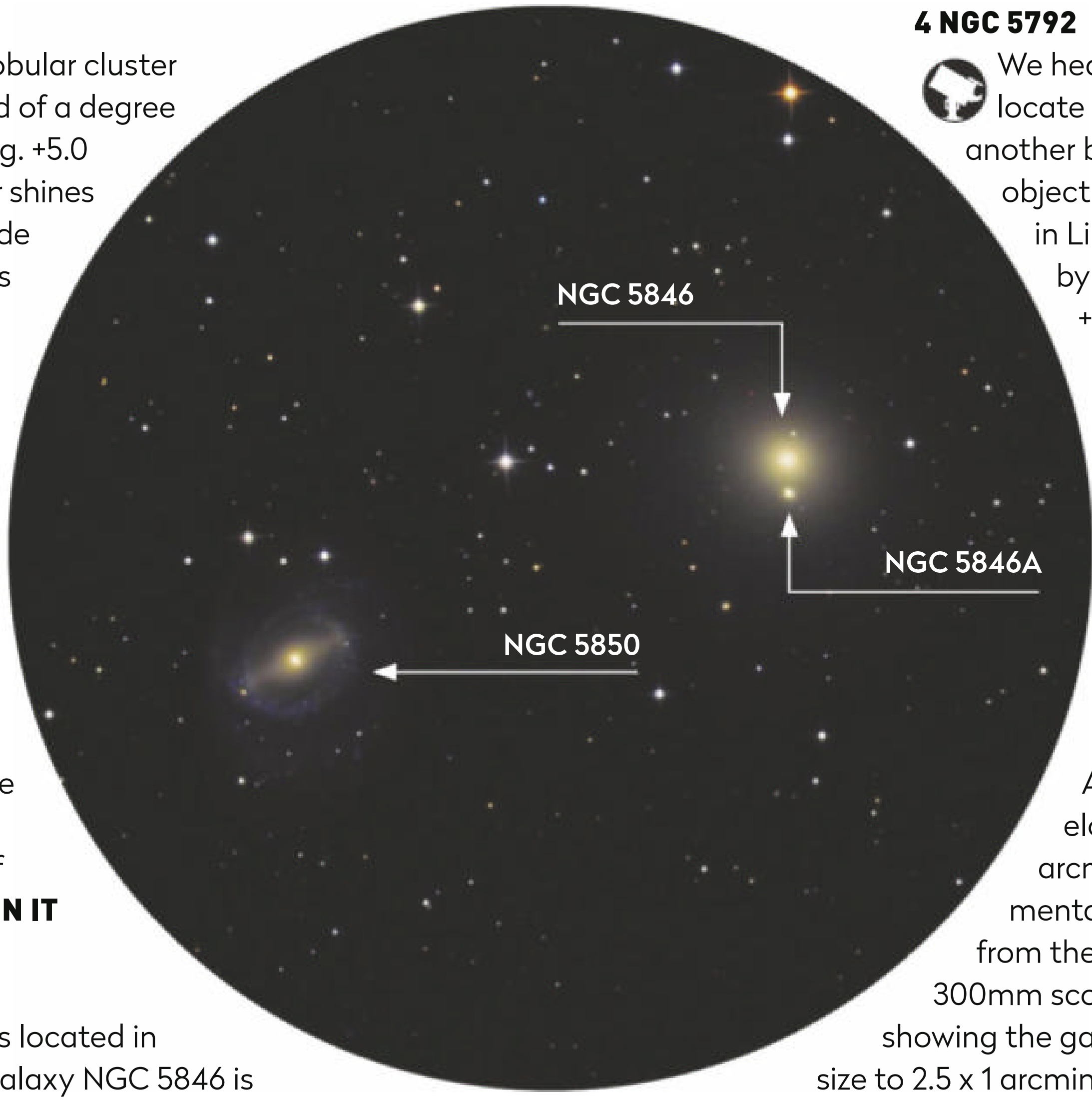
M5 is a bright globular cluster located one-third of a degree north-northwest of the mag. +5.0 star, 5 Serpentis. The cluster shines with an integrated magnitude of +5.7. A small scope shows an object around 10 arcminutes in diameter, 200x magnification resolving most of M5 well. High powers reveal many 'star strings': lines of stars running across the object. A 300mm scope shows a core around 3.5 arcminutes across, the entire globular spanning 13 arcminutes through this size aperture. There's a definite asymmetry to the shape of M5's outer halo too. ☐ **SEEN IT**

2 NGC 5846

Our next target is located in Virgo. Elliptical galaxy NGC 5846 is situated 1° east-southeast of mag. +4.4, 110 Virginis. It has an integrated magnitude of +10.1 and appears as a 1.5 arcminute glow with a star-like nucleus through a small scope. As is typical for elliptical galaxies, larger instruments tend to show the object as a brighter version of what it looked like through a small scope. There are several other galaxies nearby known as the NGC 5846 group, with NGC 5846 as the brightest member. ☐ **SEEN IT**

3 NGC 5850

NGC 5850 is a member of the NGC 5846 group, easily located 10 arcminutes to the southwest of NGC 5846. While NGC 5846 is an elliptical, NGC 5850 is a face-on barred spiral. Although it's listed as an 11th magnitude object, its surface brightness is low and a 150mm scope struggles to show it. NGC 5850 has a stellar nucleus, the surrounding core halo region being the brightest part of this object. A 250mm scope shows the bright core well, surrounded by a faint halo 2.0 x 0.5 arcminutes in size. NGC 5850 is believed to have had a high-speed encounter with NGC 5846, an event that disrupted NGC 5850's structure. ☐ **SEEN IT**



▲ **Bright ideas: with NGC 5846 as its brightest member, the NGC 5846 group includes elliptical galaxy NGC 5846A and barred spiral galaxy NGC 5850**

MICHAEL BREITE/STEFAN HEUTZ/WOLFGANG RIES/CCDGUIDE.COM, CHART BY PETE LAWRENCE

4 NGC 5792

We head 3.4° to the southwest to locate our next target, NGC 5792, another barred spiral galaxy. This object sits slightly over the border in Libra. Its location is helped by the presence of a mag. +9.6 star on its northwest edge, one arcminute from its centre. Listed at mag. +11.7, NGC 5792's surface brightness is rather low, so 'helped' may not be the correct term to use here as the guide star is bright enough to interfere with the appearance of the highly inclined galaxy. A 250mm scope shows an elongated glow, a bit over an arcminute across. If you can mentally ignore the intrusion from the ninth magnitude star, a 300mm scope improves the view, showing the galaxy's glow expanded in size to 2.5 x 1 arcminutes. ☐ **SEEN IT**

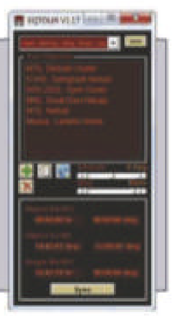
5 Palomar 5

Our next target is tricky; Palomar 5 is one of a collection of 15 globular clusters first identified on the Palomar Observatory Sky Survey plates in the 1950s. To locate it, head back to M5. From here, using our chart opposite, star hop south to locate 4 Serpentis 1.5° south-southwest of 5 Serpentis. Palomar 5 sits half a degree to the south of 4 Serpentis. Don't expect anything like the view you'd normally expect of a globular though, Palomar 5 appears as a faint haze of dim stars spread over an area defined by a triangle of mag. +9.5 and +10.5 stars. The haze will probably need a 375mm or larger scope to see, but even then don't expect an easy ride! ☐ **SEEN IT**

6 NGC 5746

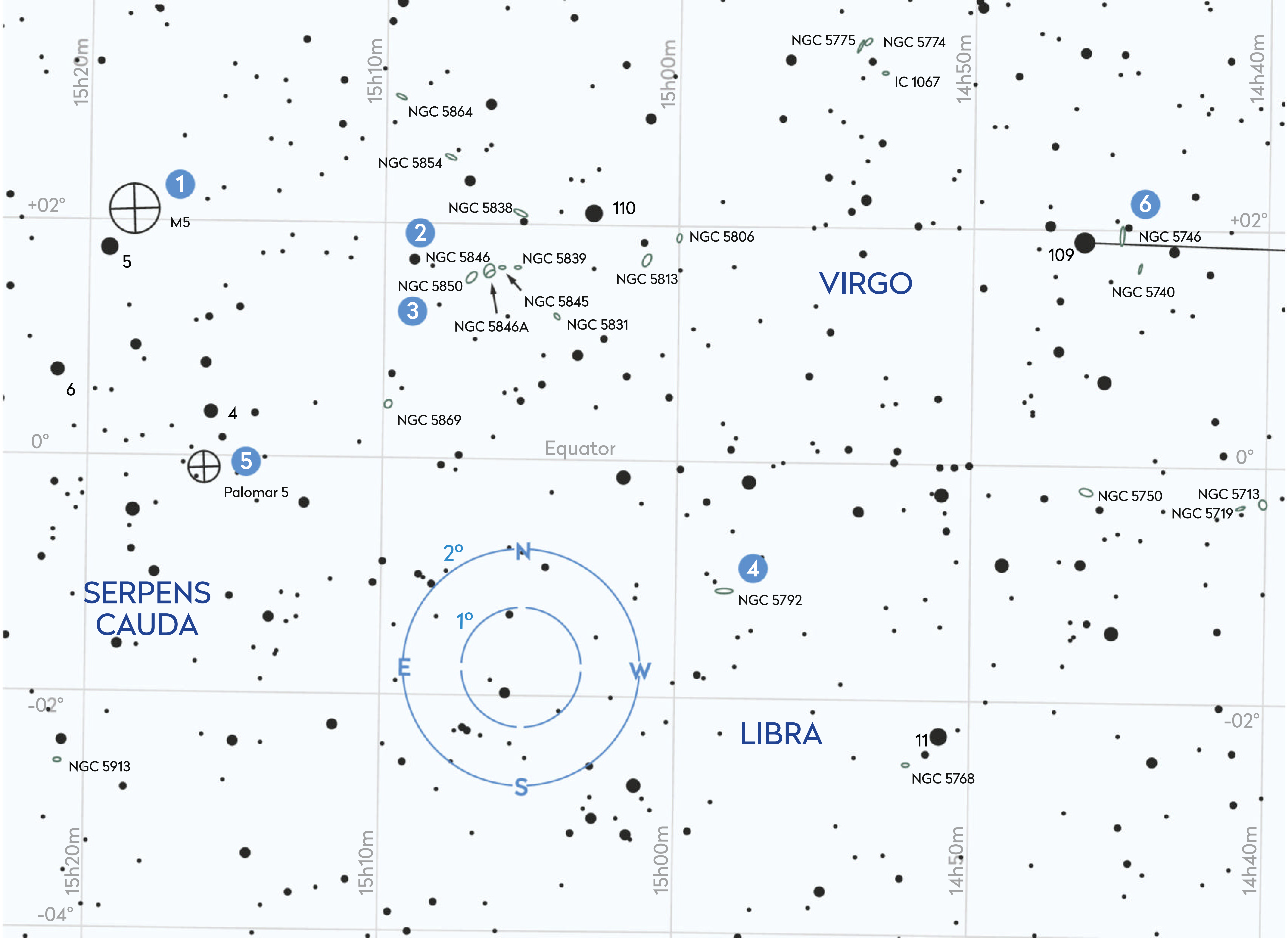
Our final object is a little easier to spot. It's an edge-on barred spiral galaxy in Virgo, catalogued as mag. +11.0 NGC 5746. It's relatively easy to find, located 20 arcminutes west and a fraction north of mag. +3.7, 109 Virginis. The galaxy's long axis is orientated north-south and it's a lovely sight through a 250mm scope, a bright central halo less than an arcminute wide but extending possibly 2 arcminutes in length. With averted vision, the galaxy faintly extends beyond this, possibly increasing its length to 5 or 6 arcminutes. A 300mm scope increases it further and shows a mottled texture near the core. This is possibly due to the presence of a dust lane running along the galaxy's length. ☐ **SEEN IT**

This Deep-Sky Tour has been automated
ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.



More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.


VIRGO
LIBRA
SERPENS CAUDA
Equator
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15h10m
15h00m
14h50m
14h40m
+02°
0°
-02°
-04°
M5
Palomar 5
NGC 5775
NGC 5774
IC 1067
NGC 5864
NGC 5854
NGC 5838
NGC 5846
NGC 5839
NGC 5850
NGC 5845
NGC 5846A
NGC 5831
NGC 5813
NGC 5806
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NGC 5746
NGC 5740
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NGC 5713
NGC 5719
NGC 5792
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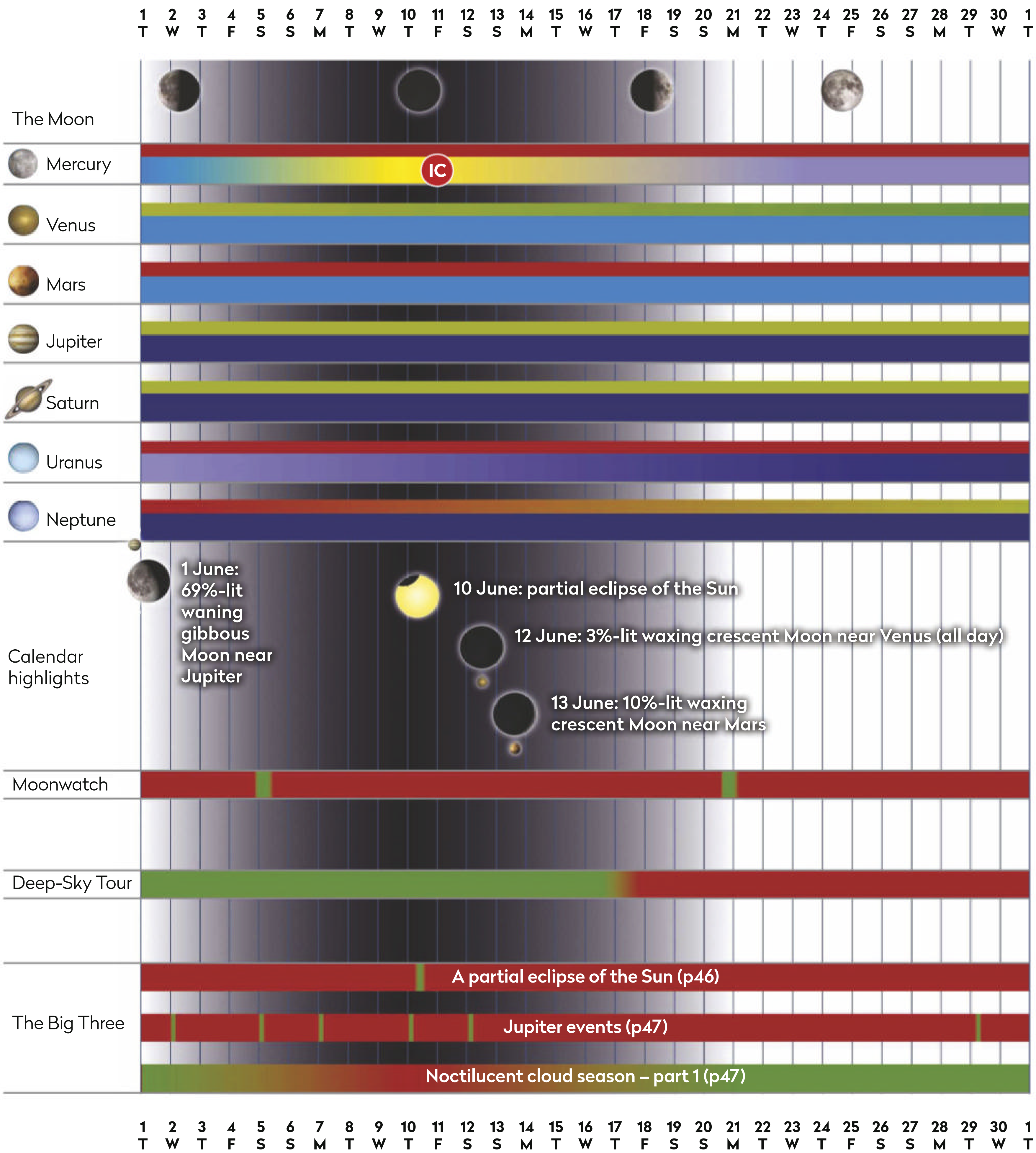
AT A GLANCE How the Sky Guide events will appear in June



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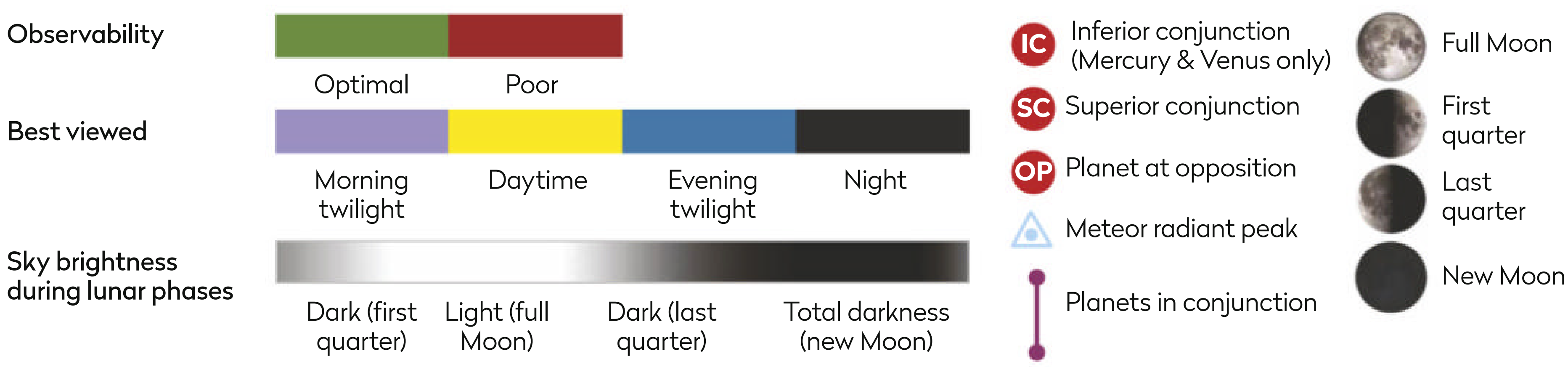
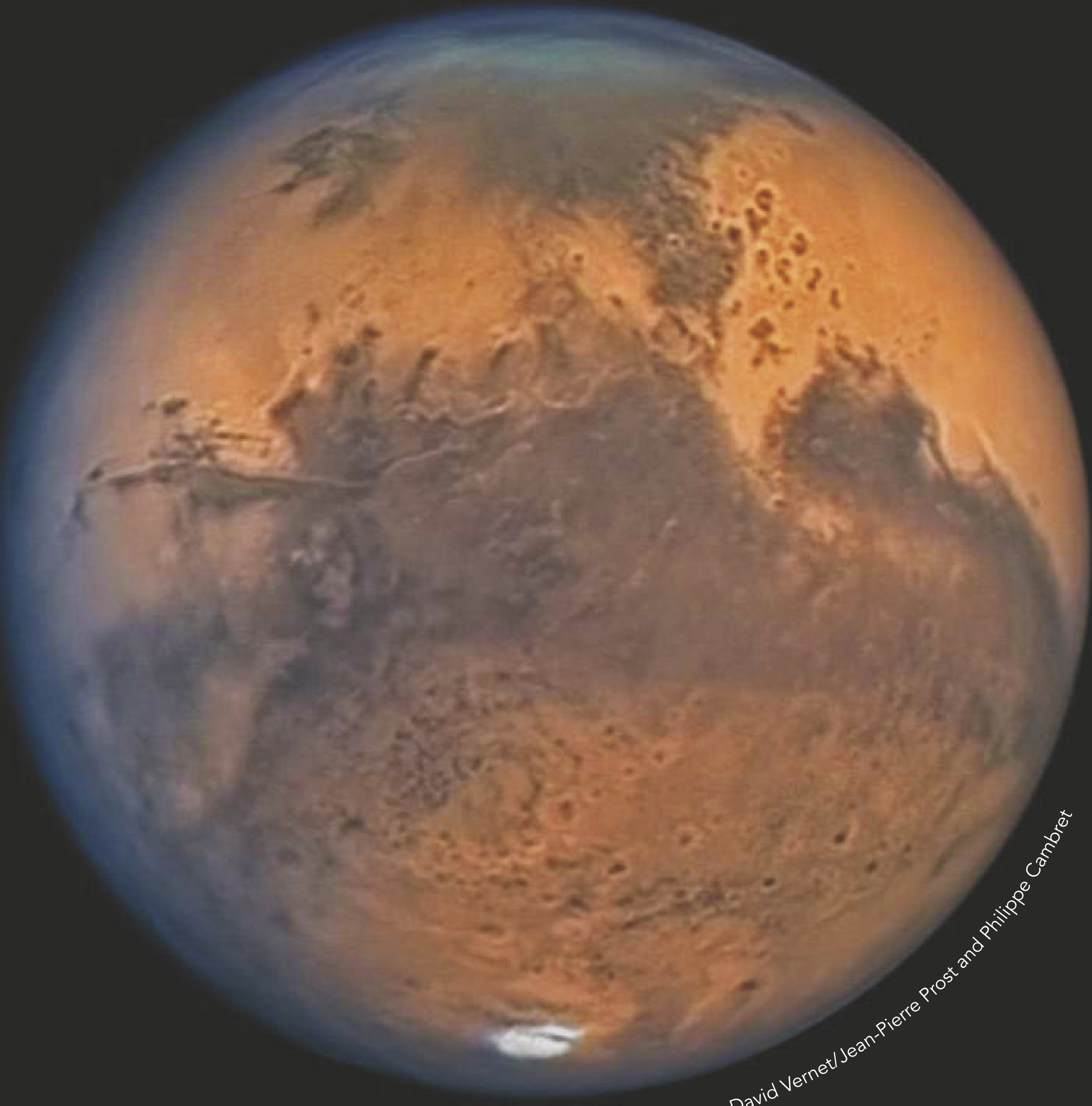


CHART BY PETE LAWRENCE

Appetite whetted?



David Vernet/Jean-Pierre Prost and Philippe Cambret

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INTRODUCTION TO ASTROPHOTOGRAPHY

A beginner's guide to PLANETARY IMAGING

The worlds of the Solar System make rewarding targets for first-time astrophotographers. **Pete Lawrence** offers tips on how to image them

Planetary imaging is a compelling side to astrophotography. If you're considering capturing the other worlds of the Solar System for the first time, or perhaps have already dipped your toes into the subject and been disappointed with the results, this article will help you understand what it's all about and why it requires special consideration. Although an extensive subject, it is still possible to get decent results with basic equipment.

In astrophotography, planets are often lumped in with the Sun and Moon under the generic heading of Solar System imaging. Although the Sun and Moon present discs that are larger than the planets, the goal is still to image tiny surface detail. Earth's atmosphere is a big problem here; variations in air temperature and density cause incoming light to deviate off-course by small amounts. As the atmosphere is moving, the cumulative effect of these deviations is a distorting 'wobble' referred to as seeing. Overcoming seeing effects is a hurdle to capturing sharp details of Solar System objects.

Seeing varies in intensity; sometimes it's bad, sometimes it's stable. It can stay the same for ages, but can also change quickly. Unless seriously poor, stable seeing periods normally do occur but can be short in duration, just seconds in length. Although you can't eliminate seeing, you can reduce its effects by taking advantage of these short periods of stability.

Point a camera at a planet and take a single shot, and you'll record what that planet looks like distorted by the seeing at that instant. You might get lucky and capture it through steady seeing, but the chances are you won't. Exposure time also makes a difference: too long and the image will reflect a 'wobble' average with lost detail, but too short using the wrong settings and the result will be underexposed and useless. You might think that the way forward would be to use a high sensitivity setting and really short exposures, but it's not as simple as upping the ISO of a DSLR because this introduces noise (unwanted artefacts). Also, pressing the shutter button at the moment of good seeing is virtually impossible.

There's more on this in the 'Capturing a planetary image' section, but first we're going to consider what the choice of telescope does to a planetary image. ▸

Astronomy expert **Pete Lawrence** is a presenter on *The Sky at Night* on BBC Four and an award-winning astro imager

ALL PICTURES: PETE LAWRENCE

Equipment matters: planetary imaging is guided by the size of your telescope and camera type. The views of Jupiter, Saturn and the Moon above were taken 'afocally' with a smartphone held to the eyepiece of various telescopes. The Moon was imaged with a 4-inch refractor and the planets with larger scopes

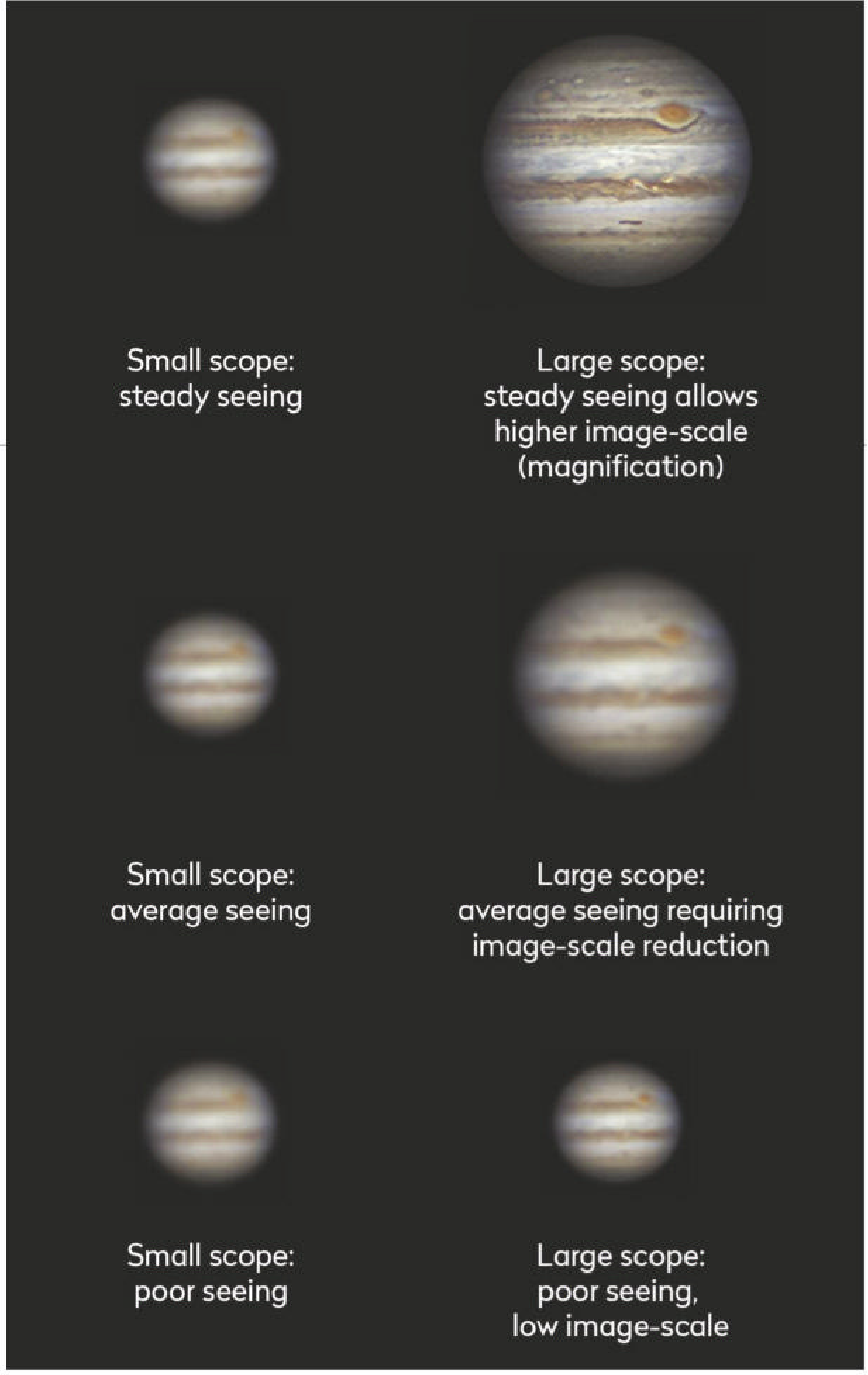
Telescopes

Planetary imaging is largely guided by telescope size: large apertures and long focal lengths are needed to deliver the really detailed stuff. Bigger apertures have more resolving power, allowing you to capture smaller detail. Unfortunately, from the UK wobbly seeing tends to prevent large scopes from fulfilling their true potential. Focal length determines image scale – in other words, how magnified something looks. Longer focal lengths lead to larger image scales, and for these you need more precisely driven mounts and more precise focus control. A larger image scale also magnifies seeing and other atmospheric distortions such as dispersion, which can create colour fringes around planets. This is more prominent around bright astronomical targets which have low altitude.

Don't discount small scopes

Smaller scopes can still get good results, but a smaller aperture will reduce the ability to resolve fine detail. Smaller instruments also tend to have shorter focal lengths, leading to lower image scales. There are advantages though; under low image scale, the distortions and wobbles from seeing appear smaller. A small scope under average to poor seeing may well present results on par with a larger instrument under similar conditions.

A small telescope will record each planet's basic shape along with larger features, if present. These



▲ **Is bigger always better? atmospheric stability (seeing) is a great leveller, as a large scope will require steady conditions to outperform a smaller one**

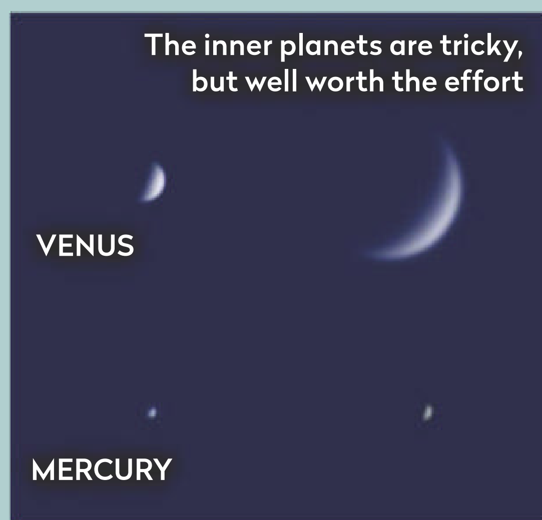
What can you expect: Imaging the inner planets

Closest to the Sun, Mercury and Venus can be tricky targets

The Solar System's innermost planets, Mercury and Venus, can present interesting challenges as they never stray too far from the position of the Sun in the sky. Mercury is the trickiest to image because – during the period of evening or morning twilight – it tends to be positioned quite low against the horizon. This causes its small apparent size to be badly affected by seeing. But it should be possible to show its phase with smaller kit if you can catch the planet in a moment of steady seeing.

Venus presents a larger maximum size and can appear further from the Sun than Mercury. When at higher altitude, the effects of reduced atmospheric turbulence give it a more stable appearance. Despite this, Venus is a tricky world to image in terms of atmospheric detail, and any variations in its bright globe-covering clouds tend to be subtle at best.

The phase of Venus is fairly easy to record, especially when the planet appears as a crescent. This occurs between greatest eastern elongation and inferior conjunction in the evening sky, and between inferior conjunction and greatest western elongation in the morning sky. Greatest eastern elongation next occurs on 29 October, with inferior conjunction on 8 January 2022.



The inner planets are tricky, but well worth the effort

ALL PICTURES: PETE LAWRENCE

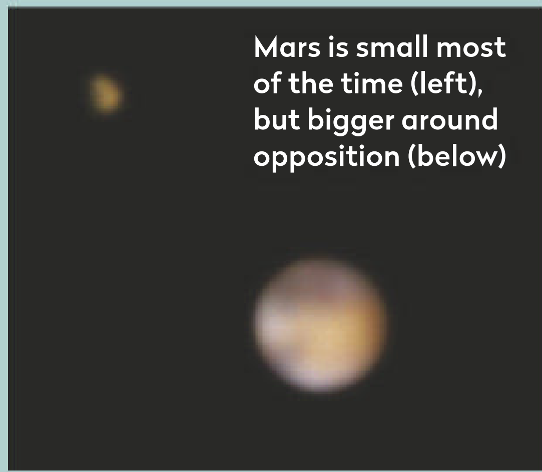
What can you expect: Imaging Mars

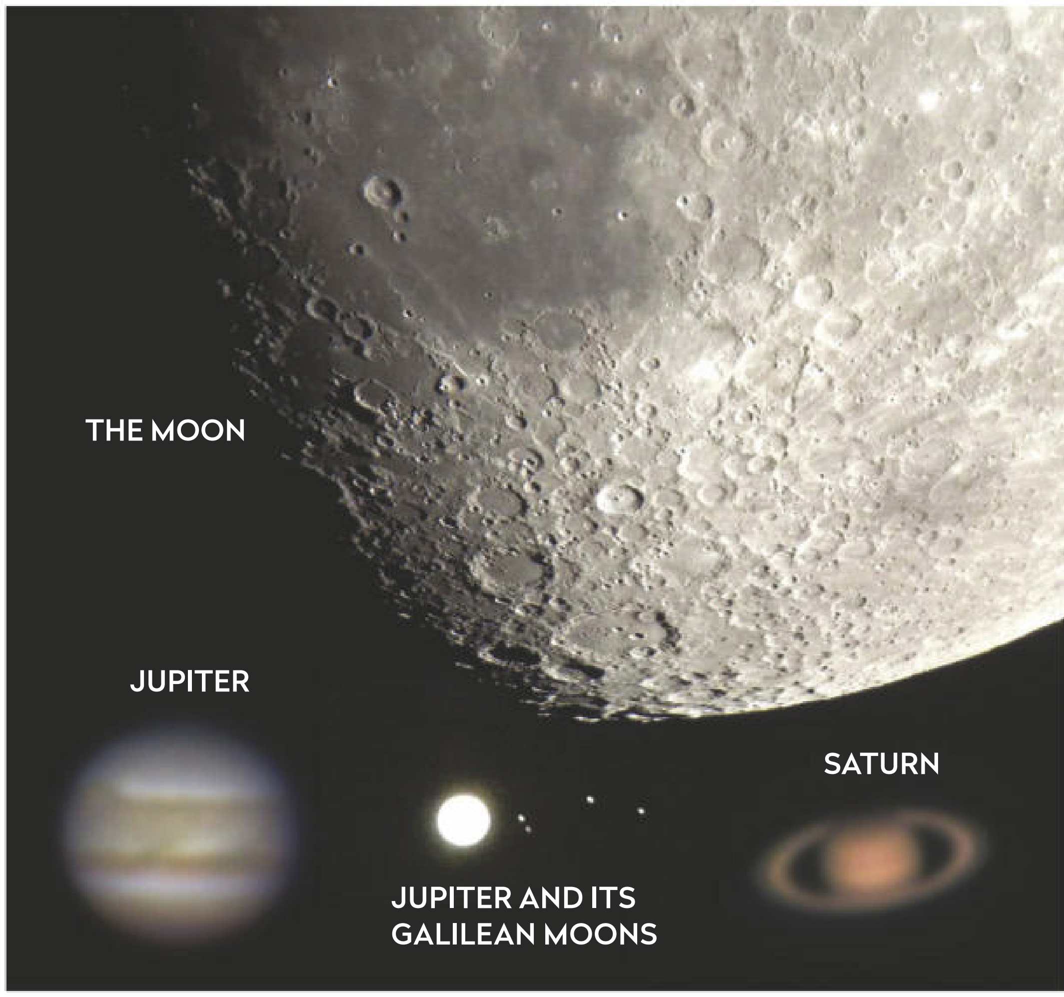
The Red Planet can be a prime target at its best

Timing is everything with Mars, as the planet changes size quite dramatically depending on where it and Earth are in their respective orbits. Mars appears largest over the period of a few months centred on opposition, a time when the planet is in the opposite part of the sky to the Sun and closest to Earth.

Away from this period, which occurs every 2.1 years, Mars presents a small to tiny apparent diameter, which makes it tricky to get any detail from. When near opposition, Mars presents a reasonable disc size, which is coloured a distinct orange-brown. The planet's polar caps are bright and can often be recorded quite easily with basic kit. These change in appearance with the Martian seasons through, so don't be disheartened if you don't record them – they may just not be that visible.

There are dark patterns on the planet's surface caused by exposed rock within the brighter, sandy desert regions. The larger dark features should be within range of basic kit but what's visible depends on which face of Mars is being presented towards Earth when you take your shot. However, detail like that won't be available again for some time: Mars's last opposition was in early October 2020 and the next isn't due until early December 2022.


Mars is small most of the time (left), but bigger around opposition (below)



include things such as the dark surface areas and bright polar caps on Mars; the main belts on Jupiter along with it four Galilean moons; and the rings of Saturn, a planet also blessed with several bright moons. As resolution and image scale are reduced for small scopes, a single still image can work just fine. This allows results to be obtained from setups such as a DSLR attached to a telescope, or a smartphone pointed down a focused eyepiece.

With larger telescopes come more options, but again, if you're just starting out, single still images can still be used to capture the larger aspects of a planet.

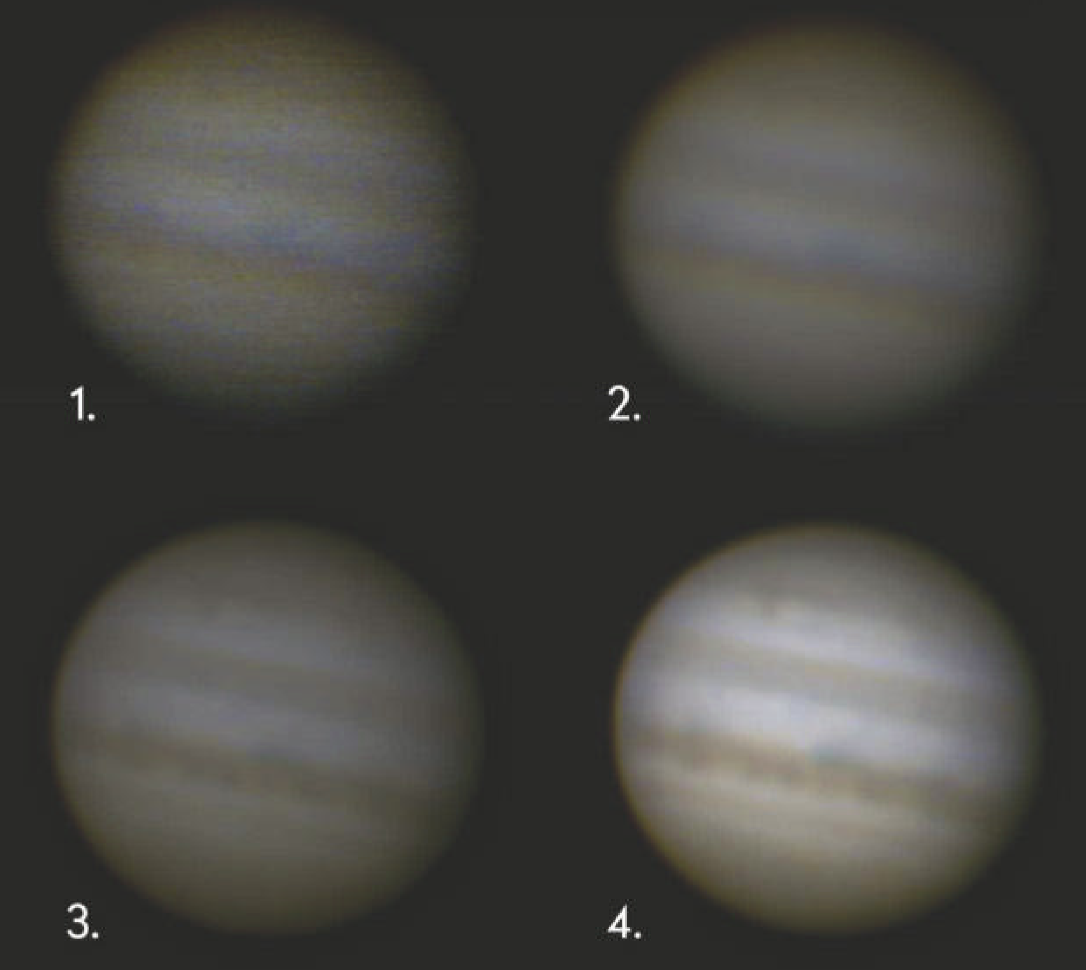
A telescope's focal ratio is also useful to know. This is its focal length divided by the aperture using the same units. For example, a 100mm scope with a focal length of 1,000mm has a focal ratio of 10, normally written as f/10. A telescope's effective focal length can be adjusted using optical amplifiers like Barlow lenses. If we fitted a 2x Barlow to our 100mm scope, it would double its native 1,000mm focal length to an effective value of 2,000mm. Here, the focal ratio would be increased to f/20 and the image scale doubled. As a rule of thumb, under poor seeing aim for focal ratios of f/10–f/15; for average conditions aim between f/15–f/25; and for excellent conditions, f/25–f/40. In the UK, excellent seeing conditions are quite rare! ►

▲ Above left: Hand-held or mounted (inset), afocal imaging with a smartphone's camera can yield good images of the Solar System

Above right: Examples of images taken afocally with a smartphone camera

Capturing a planetary image

Using registration-stacking software to improve an image of Jupiter



1: A noisy single image. 2: 300 single images after stacking. 3: Sharpened using RegiStax wavelets. 4: Final processing in image editing software

When you're imaging planets, there are a few special considerations to do with the way you take the photo – or 'capture the data' if you're using astrophotography terms. Prime among these is the technique of lucky imaging, which is the process of capturing images of the planets in those fleeting moments when the seeing is good. Rather than attempt precise shutter button pressing, the usual method of lucky imaging is to capture a continuous sequence of short exposures over a period of time, either as individual shots or contained in a video file. Some of these frames will be good, some will be poor. You can then run the captured file through registration-stacking programs such as RegiStax or AutoStakkert! (both free) – either as individual shots or a movie file – to sort them in terms of image quality and reject the poor ones. The good ones are then aligned and averaged together to produce an image which can be sharpened and tweaked as required (see left).

Why video files are best

The process is remarkably quick and efficient. It can be applied to still shots of, say, the Moon taken with a DSLR camera, and some have also managed to use registration-stacking on converted DSLR movie sequences. There is a caveat with DSLR movies though, as their frames tend to be compressed to

What can you expect: Imaging the gas giants

Jupiter and Saturn make great first-time planetary subjects

Both Jupiter and Saturn are excellent targets for smaller instruments. Jupiter presents a decent apparent size which can be captured to reveal its oblate shape. Get the exposure right and you can record the two main, dark equatorial belts that run parallel either side of the planet's equator.

The polar regions also tend to look dark and this is fairly easy to record too. If you're getting good results with the disc, try and image the planet's four brightest satellites too. These are the Galilean moons, Io, Europa, Ganymede and Callisto. They are easy to record as bright dots, but see if you can image the shadows they sometimes cast on the planet's atmosphere as well.

Saturn's disc is harder to image in terms of detail, its belts and zones being far more subtle than those of Jupiter. However, it makes up for this with its rings, and a basic photo showing these encircling the planet's globe will be something to cherish. As well as the disc and rings, see whether you can capture some of Saturn's brighter moons. If you really want to push the boat out, take images of these at, say, 10-minute intervals and animate the results to see the moons move!

▲ While the main features of Jupiter and Saturn can be captured in a small scope, the moons also make good targets

ALL PICTURES: PETE LAWRENCE

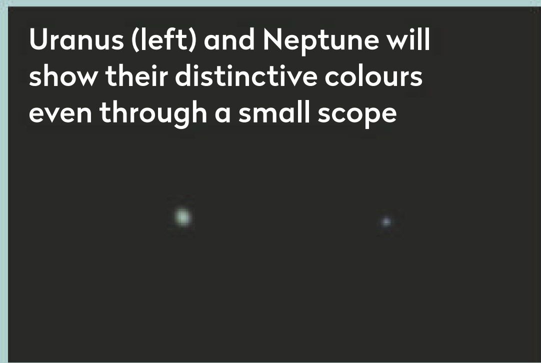
What can you expect: Imaging the ice giants

Furthest away, Uranus and Neptune can be elusive targets

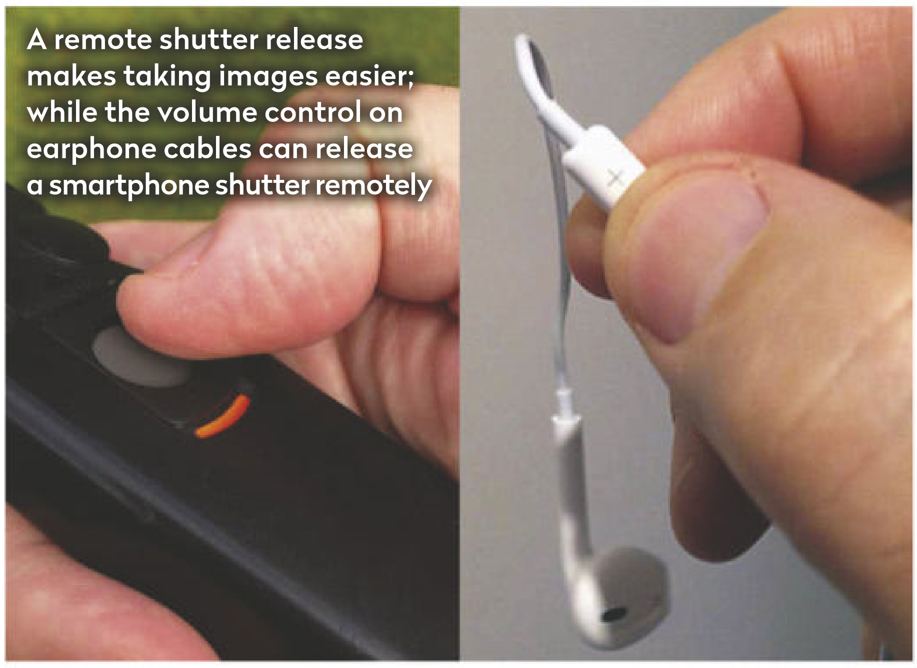
The Solar System's outermost planets, Uranus and Neptune, give even high-end setups trouble. Ironically, Uranus is the best placed planet visible from the UK towards the end of 2021, appearing highest above the horizon of all of them when due south. However, even a high image scale is unlikely to show much more than just a small circular disc.

Uranus has a lovely green-blue hue to it, which requires careful exposure to capture properly. Go too long and the planet will overexpose to white. Its brighter moons can be photographed too, but in order to do this you'll need to up the image scale. It's also important to make sure there's no high cloud or moisture on your optics when attempting this as you'll need to overexpose the planet, which can cause its light to bleed across the area where the moons will appear. Don't feel too bad if you fail: they are tricky to pick up.

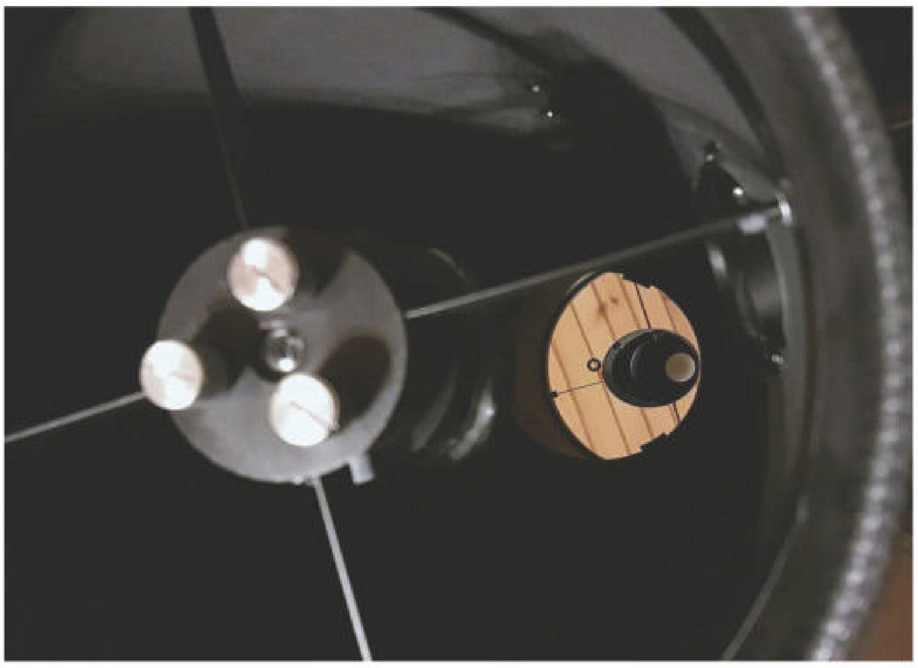
Neptune has a beautiful blue hue, and an even smaller apparent disc size than that of Uranus. Its largest moon, Triton, can be recorded even with quite basic kit. Just make sure your focus is spot on and that you use an accurate telescope drive.



Uranus (left) and Neptune will show their distinctive colours even through a small scope



A remote shutter release makes taking images easier; while the volume control on earphone cables can release a smartphone shutter remotely



▲ **Above right: For the sharpest images with mirror-based scopes, check and adjust the collimation**

save storage space. Decompression and subsequent processing can introduce artefacts and features that aren't real.

Planetary imaging is rewarding but it does take time to master. If you do decide to give it a go, here are a few additional things to consider. It's important to let your telescope cool to its surroundings, allowing the air in the tube to become still. Aim to leave a small scope outside for around 30 minutes; while for a medium scope (up to 250mm) it should be 1–2 hours; and for a large scope it will be 2–4 hours or longer.

If you're using a DSLR camera, invest in a remote shutter release cable or better still, a wireless remote. If you're using a smartphone, many have cameras which can be remotely operated by pressing a volume control button on an attached earphone/headphone cable. This avoids unwanted telescope wobbling when pressing the shutter button. A tracking drive isn't strictly necessary but it will make things easier. If you're using a reflector or other mirror-based scope such as a Schmidt-Cassegrain, make sure it's properly collimated. Often regarded as a scary exercise, there are enough videos and tutorials on the internet to hand-hold you comfortably through the process. Collimation makes sure the scope's optics are properly aligned, and the difference between an uncollimated and collimated scope can be significant.

Now all you need is some clear weather, stable seeing and of course some planets to view. Good luck!

Taking it further

The camera you need to capture quality data for your planetary images

The next step beyond capturing still frames is to venture into lucky imaging using a planetary camera. These are high frame-rate devices, a bit like an industrial strength webcam, capable of capturing video files made up of uncompressed frames. Lucky imaging, as explained in the main article, helps reduce the effects of seeing. As well as requiring additional expenditure, you've also got to consider how you will control a planetary camera. The normal option is to use a laptop, and various free or low-cost control programs are available for download, popular examples being SharpCap and FireCapture.

Clouds over Mars: one of Emily Lakdawalla's favourite images shows the Red Planet, as taken by the Mars Orbiter mission in 2016. She colour-adjusted the clouds to make them white

ISRO/ISSDC/EMILY LAKDAWALLA

THE PEOPLE WHO PROCESS THE COSMOS

Data from space missions is there for everyone to mould into awe-inspiring images. **Govert Schilling** finds out what drives some of planet Earth's best data processors

MEET THE EXPERTS
EMILY LAKDAWALLA

Planetary scientist Emily Lakdawalla has been interested in image processing since working with Landsat satellite data in 1994. "The most satisfying part is enjoying the beautiful views of other places in the Solar System," she says. The biggest challenges, she indicates, include re-creating natural colours.

She recalls the drama in 2005 when ESA's Huygens probe descended to Titan's surface. "The first images got leaked," she recalls, "and soon, amateurs had produced panoramas that exceeded what the Cassini-Huygens imaging team was doing."

She can't wait to lay her hands on images from the Jupiter Icy Moons Explorer (JUICE), launching in 2022, and the Europa Clipper mission.

TOP TIPS

▶ Processing space pictures uses the same skills as holiday snaps. Cropping, rotating, adjusting brightness and contrast, and adding fill light can make a good image great.

▶ Space cameras have narrow fields of view, so space images are pieces of mosaics; use photo-merge applications to assemble these.

▶ Every space camera is different, so get to know one at a time. For example, start with the Mars rover RAW images (**www.jpl.nasa.gov**), then Cassini (**bit.ly/3dl6qRE**) and then Rosetta (**bit.ly/3nbe0Hn**).

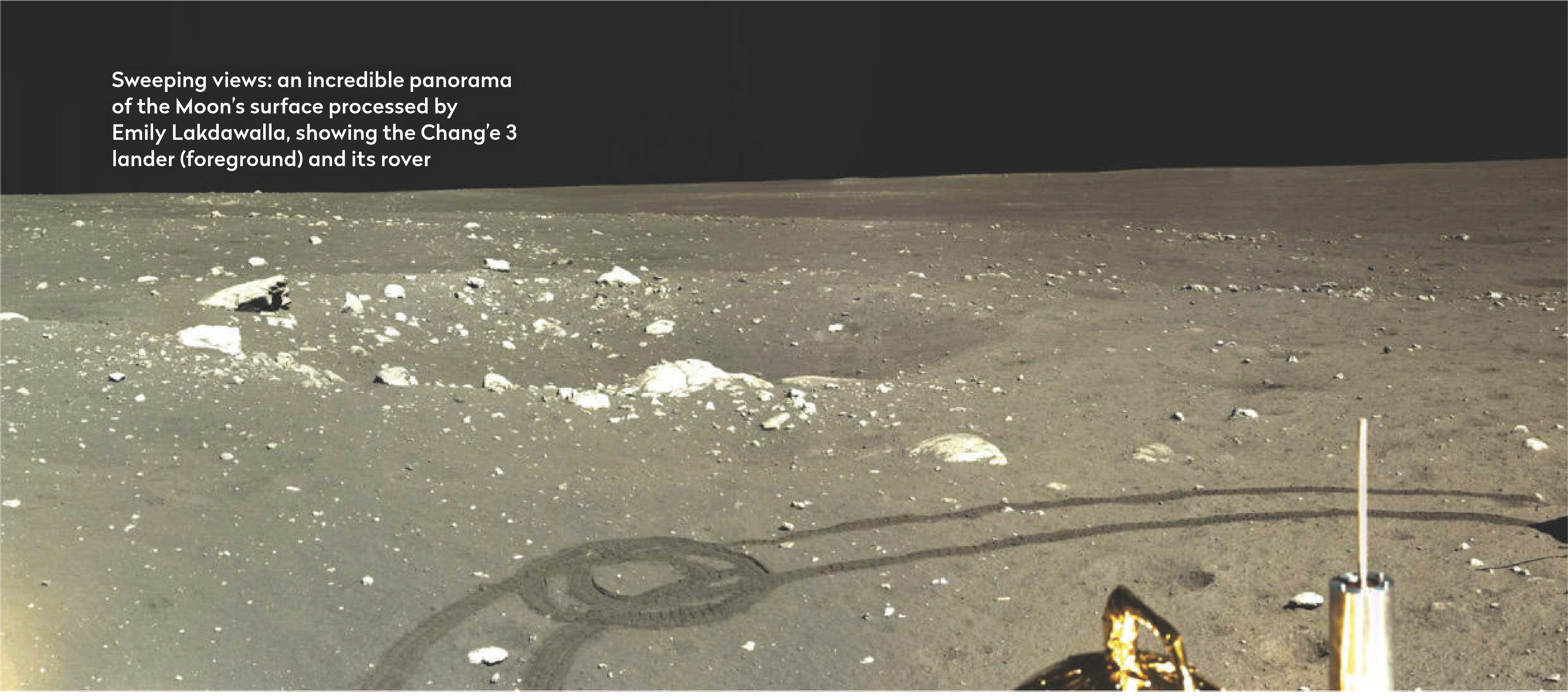
Twitter: @elakdawalla

At a press conference moments after the landing of the Perseverance rover on Mars, NASA's science chief Thomas Zurbuchen invited the audience to, "take a look at the RAW images, and play with them," adding "What can you find on those pictures?"

Planetary scientist Emily Lakdawalla (see box, left) didn't need an invitation. As soon as the first photos of the eerie landscape captured by Percy's navigation cameras were published online, she was busy removing geometric distortions, adjusting colour levels and interpreting metadata on the image files.

Meanwhile, 3D visual artist Mattias Malmer (see box, page 68) was using the RAW images to reconstruct the landscape in Mars's Jezero crater so his kids could visit the Red Planet wearing virtual reality goggles. Malmer is doing the same with data from NASA's Curiosity rover ("I'm very much in love with that landscape," he says), and with the scant images that the Russian Venera landers captured from the surface of Venus in the 1980s.

You might think that professional planetary scientists would hate 'amateurs' to dabble with their images, but instead, "they love it," says Lakdawalla. "They don't have the time and the expertise to do it this way. Sometimes they ask me permission to use my results in their slide presentations." ▸



Sweeping views: an incredible panorama of the Moon's surface processed by Emily Lakdawalla, showing the Chang'e 3 lander (foreground) and its rover

▸ Malmer fondly recalls how his 3D shape model and stereo images of comet 67P/Churyumov-Gerasimenko – based on data from ESA's Rosetta spacecraft – were used at an official presentation in the Cité des Sciences in Paris in 2014. "That's how I got the French president to wear silly glasses," he says.

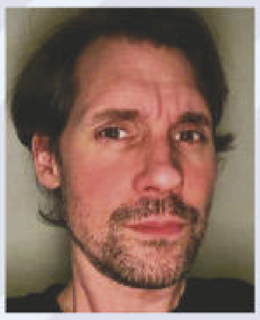
Something equally exciting happened to graphic designer Jason Major (see box, page 71). When the first photos of Jupiter's Great Red Spot came back from NASA's Juno spacecraft in July 2017, Major skipped dinner and was one of the first to rapidly process them. His results were featured by NASA and appeared in *Newsweek*, among other publications.

How you can help

When it comes to processing data captured by robotic explorers and space telescopes, there's really a lot the public at large can do. For starters, every space mission yields more RAW black and white images (taken through various colour filters) than professional scientists can process into the colourful images depicting the beautiful worlds and our Solar System. As a result, there's ample opportunity to

▲ **Get involved: an example of a RAW black and white image of Mars from the Perseverance Rover – such images are readily available for anyone to work on**

MEET THE EXPERTS
MATTIAS MALMER



Living just outside Stockholm, Sweden, 3D visual artist Mattias Malmer has been interested in astronomy since he was a little kid. "I never grew out of the dinosaur/space phase," he says. When he incidentally stumbled upon the RAW images at NASA's Planetary Data System, he instantly started to piece together panoramas and got hooked.

Recently, he has been dabbling with 3D reconstructions of space scenes, to load them into a virtual reality (VR) environment for his viewing pleasure using his HTC VIVE VR system.

He likes to maintain a sense of reality in his images. "I really dislike what is done to many of the Juno images," he says. "It is some kind of competition in who can make the most outlandishly extreme colour saturation possible." His own favourite is a natural colour view of Jupiter's Great Red Spot eyeing tiny Ganymede in the distance.

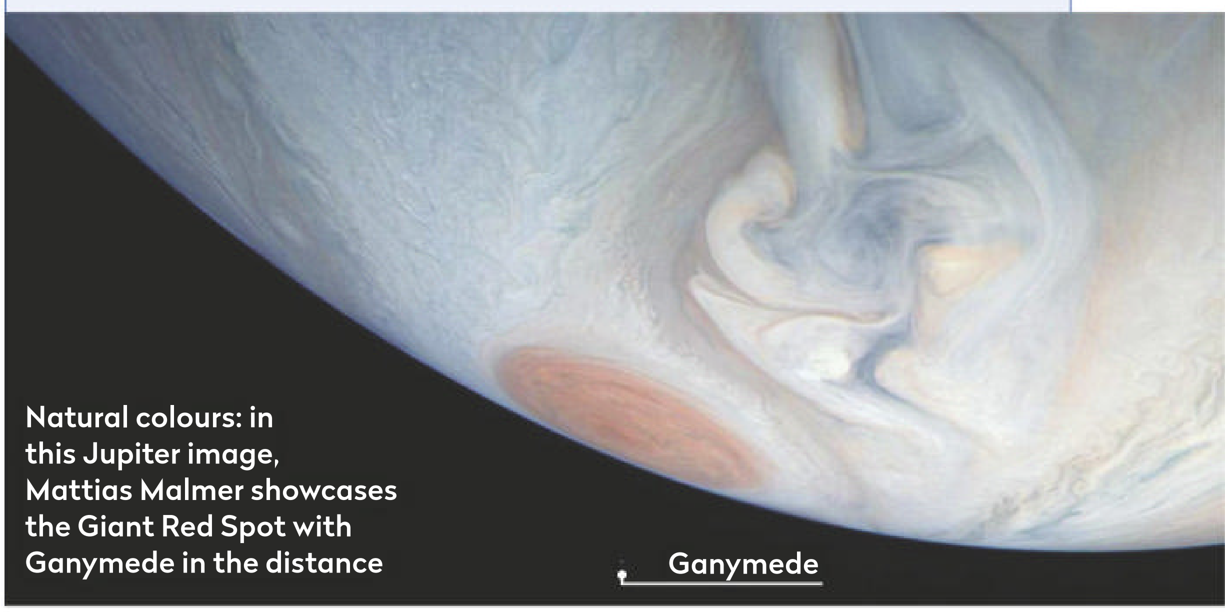
TOP TIPS

▶ Try to move away from Adobe Photoshop and aim to learn some compositing software, which makes building processing pipelines much easier and more reusable.

▶ Make sure to dig up the calibration reports of the cameras used in the missions; there is always some great information to be had.

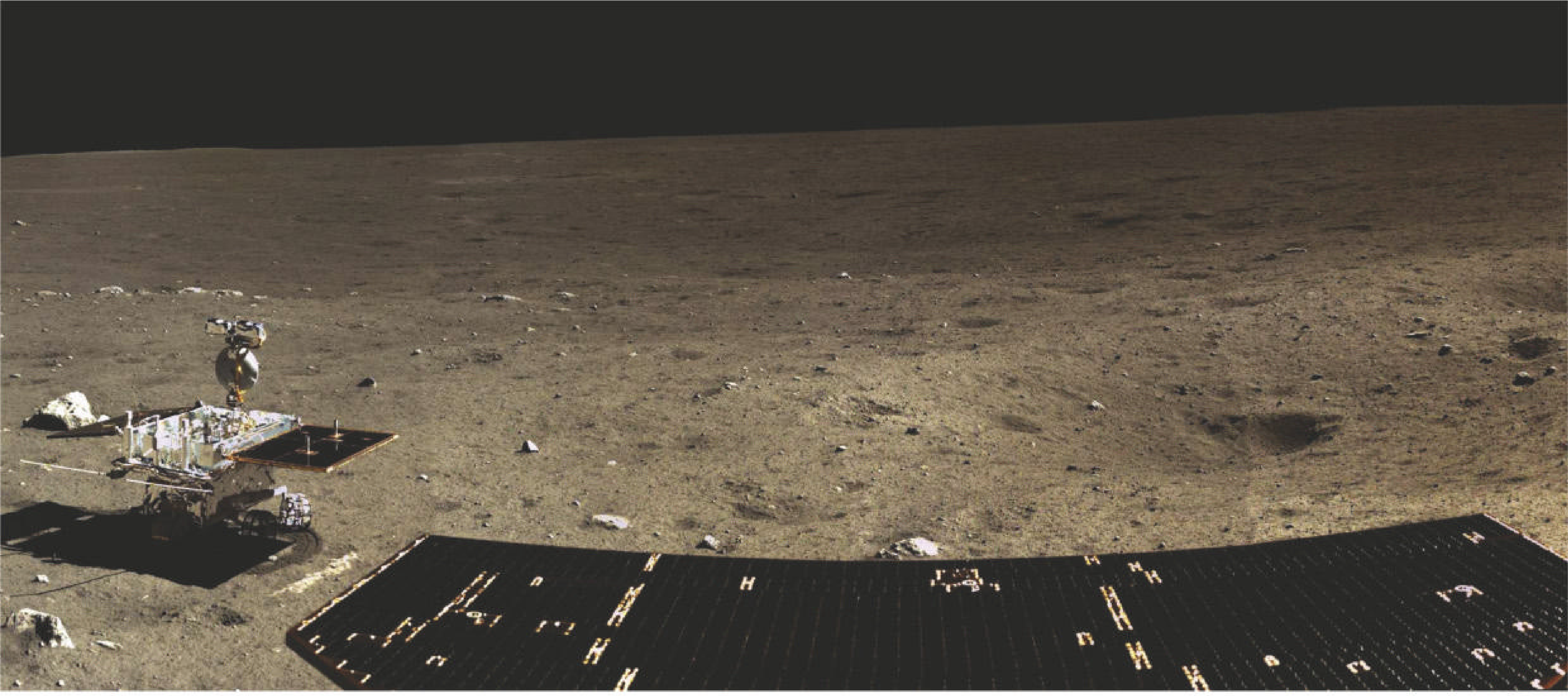
▶ Learn from what other people are doing by following people with the same interest in space image-processing on social media.

Twitter: @3Dmattias



Natural colours: in this Jupiter image, Mattias Malmer showcases the Giant Red Spot with Ganymede in the distance

CHINESE ACADEMY OF SCIENCES/CHINA NATIONAL SPACE ADMINISTRATION/THE SCIENCE AND APPLICATION CENTER FOR MOON AND DEEPSPACE EXPLORATION/EMILY LAKDAWALLA, NASA/JPL-CALTECH, NASA/SWRI/MSSS/MATTIAS MALMER, NASA, NASA/HST, NASA/ESA AND M. LIVIO AND THE HUBBLE 20TH ANNIVERSARY TEAM (STSCI)/JUDY SCHMIDT



▲ Remove unwanted artefacts: a reseau mark (circled) is visible in this Apollo 12 mission image...

▲ ...and a RAW Hubble image of the Pillars of Creation shows extensive cosmic ray streaks

create something no one has ever seen before, especially when you learn how to combine various photos into one large panorama or photo mosaic. Indeed, it takes quite a bit of practice and perseverance. For example, you need to learn how to deal with geometric camera distortions and how to remove so-called reseau marks (small crosses) or, in the case of Hubble photos, cosmic ray streaks.

All of this is very much stimulated by NASA. In fact, the main camera of the Juno spacecraft isn't even a core science instrument. Its main goal was encouraging public engagement and outreach. The RAW Juno images need a lot of processing (without it, you would hardly be able to recognise Jupiter at all), and all over the world, people like seasoned image processor Seán Doran (see box, page 70) are using the data to create stunning views of the giant ▸

MEET THE EXPERTS
JUDY SCHMIDT

In 2012, the European Space Agency (ESA) ran a contest called Hubble's Hidden Treasures. "It was shocking to me to discover that all these images were out there for anyone to look at and process for themselves," says graphic designer and website developer Judy Schmidt, who lives in Modesto, California. After the contest ended, she simply never stopped. "When dealing with space, it's important to be able to see the faintest, darkest details possible, because a lot can be hidden in them," she says. "A common mistake is working in a room that is too bright, or with a display that's too dark; either can prevent you seeing all the details in the darker parts of images."

TOP TIPS

▶ Realise that no one owns the Hubble images and they're in the public domain; you don't need permission to do anything you want with them.

▶ Make sure you have a decent computer and a bright monitor with a good colour gamut – the range of colours it is capable of displaying.

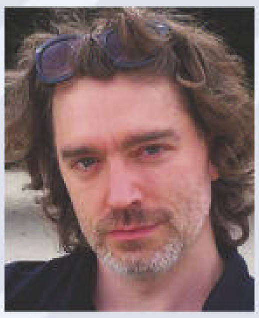
▶ Remove cosmic rays by automatically selecting them (they're typically a bright pure colour) and then expand the selection by one or two pixels.

Twitter: @SpaceGeck

Majestic: Judy Schmidt's rendering of a dust pillar in the Carina Nebula

A sense of scale: Seán Doran effectively combines images of the Curiosity rover with data from the HiRISE camera on the Mars Reconnaissance Orbiter, to show the rover against a vast Martian backdrop

MEET THE EXPERTS
SEÁN DORAN



While watching Stanley Kubrick's *2001: A Space Odyssey*, artist Seán Doran, who lives in London, decided to update all the Jupiter shots in the film with the newest data available. Ever since, most of his work has been with video. An example is his film *Earthbound*, the result of about a year's worth of research into the ISS archive. "It all started out as a general hobby and an excuse to improve my image-processing skills," he says, "but now I earn some income from it."

Doran runs four PCs, including a heavy-duty workstation with 128 gigabytes of RAM, a 16-core processor with a 16-gigabyte graphics processing unit, and 30 terabytes of storage space. As for still images, he also likes to create 3D landscapes by combining Curiosity images with data from the HiRISE camera on NASA's Mars Reconnaissance Orbiter. "It's akin to being a photographer on Mars," he says.

TOP TIPS

▶ Keep up to date with all that's happening in the field, from data access to image processing, through the very supportive community on the **www.unmannedspaceflight.com** forum.

▶ Having a fast computer helps, but devising efficient workflows using batch scripting can really eliminate drudgery; spending time early on this aspect will repay itself a hundredfold.

▶ Making films and images is a form of therapy; every day there is new data and a new creative puzzle to solve.

Twitter: @_TheSeaning

▸ planet's cloud patterns, sometimes with strongly exaggerated colours. "I am an artist," says Doran. "For the Juno images, I went to extremes in processing. I would call it stylised realism."

Earth on film

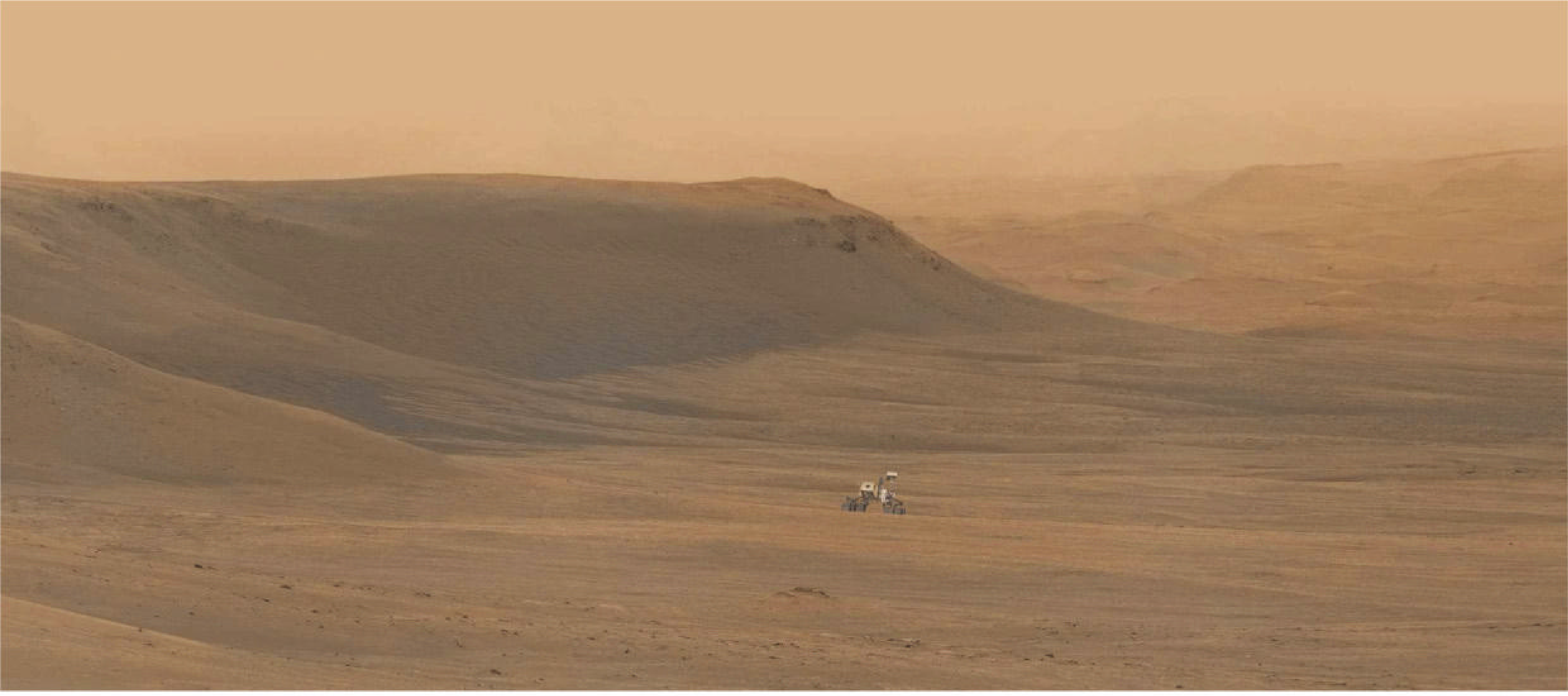
Doran has also made incredibly beautiful and very realistic real-time movies of our home planet, based on zillions of images captured from the International Space Station (ISS). His mesmerising film *Orbit*, which can be watched on YouTube, was shown on the big screen in London's Natural History Museum. He is now working on similar projects for the Sun and the Moon, using data from NASA's Solar Dynamics Observatory and the Japanese Kaguya Moon mission.

Solar System objects are popular with 'amateur' astronomical image processors. According to Major, "It's much easier to relate to them in scale and detail than, say, images of nebulae or galaxies – however beautiful those may be." But others, like Judy Schmidt (see box, page 69) work almost entirely with archived data from space telescopes, in particular Hubble.

Joe DePasquale, an image-processing specialist at the Space Telescope Science Institute in Baltimore, confirms that. "There are no restrictions," he says. He has often worked in close cooperation with Schmidt. He's not afraid – or aware – of any form of 'misuse' by

NASA / JPL-CALTECH/MSSS/SEÁN DORAN SEAN DORAN/YOUTUBE X 2, NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE/JASON MAJOR

▲ Two stills from Seán Doran's film *Orbit*, available on YouTube, where time-lapse photography from the ISS is converted to real-time video



outsiders. "I think most people who go down the path of learning how to process Hubble data have a very strong interest in science and astronomy, and have a strong desire to 'get it right'," he says.

Schmidt is now working on large Hubble data sets of nearby and interacting galaxies. "Of course, I'm also always looking forward to whatever new things enter the database," she says, "because I never know when something new and exciting might turn up. The cosmos has many secrets yet left to unravel."

Govert Schilling is an astronomy journalist and broadcaster, and author of *Ripples in Spacetime.* The asteroid 10986 Govert is named after him

Try it yourself

Resources to get you started in space data processing

For RAW images from US planetary missions, visit NASA's Planetary Data System at **pds.nasa.gov**. Slightly more accessible because of its graphic user interface is the Outer Planets Unified Search (OPUS) website at **pds-rings.seti.org**, which focuses on Jupiter and beyond. Juno images may also be found at **www.missionjuno.swri.edu/junocam/processing**.

RAW Hubble images can be retrieved from the Barbara A Mikulski Archive for Space Telescopes at **archive.stsci.edu** or, if this is too overwhelming, visit **hla.stsci.edu** to access the Hubble Legacy Archive.

Images are usually stored in FITS format (Flexible Image Transport System), but can be converted to TIFF (Tag Image File Format) through the free software package FITS Liberator at **esahubble.org/projects/fits_liberator**, so they can be processed by commercial software like Photoshop.

Don't miss Emily Lakdawalla's online course at **bit.ly/32O04tL** or Judy Schmidt's tutorial at **bit.ly/3sCIbZ9**, and find out more about processing RAW data on the *BBC Sky at Night Magazine* website at **bit.ly/3v5j9nd**.

MEET THE EXPERTS

JASON MAJOR

Graphic designer Jason Major first came across astronomical image processing in 2008. "I love images that make you feel like you were there with the spacecraft looking at the same scene, as if the on-board cameras were your own two eyes and you were seeing the beauty and majesty of our Solar System first hand. With the data that's online and available to the public, I can finally feel like I'm a deep space photographer sending postcards home for all to enjoy."

Major is especially fond of the Saturn images obtained by Cassini. "The Saturnian system is amazingly beautiful," he says. "There's a physicality to those objects that I really enjoy." His favourite result is his mosaic of 11 colour composites – Cassini's final full-planet view of Saturn before its 'death dive' into the atmosphere in September 2017

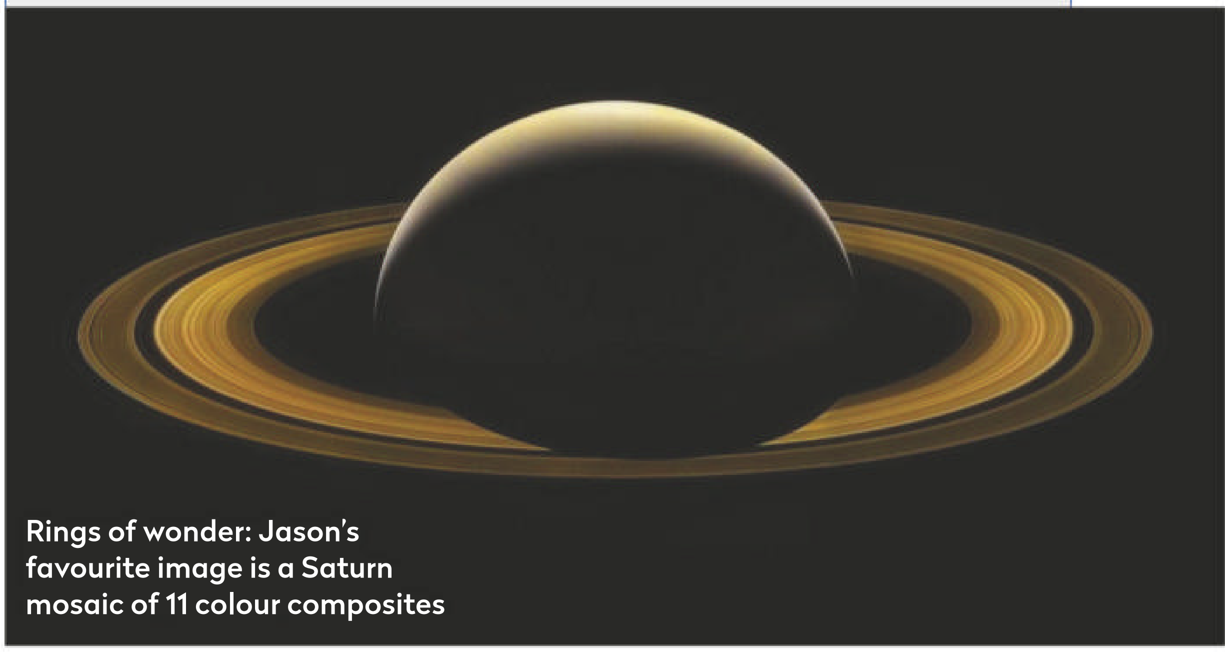
TOP TIPS

▶ Find the best versions of your source data. The less compression, the better and more accurate your final results will be.

▶ Clean up noise and artefacts. Space is full of radiation that gets picked up on spacecraft imaging sensors; you'll need to learn to recognise this and remove it.

▶ Be creative. Everyone has their own eye and vision for what looks good; push your interpretation to make something exciting to you!

Twitter: @JPMajor



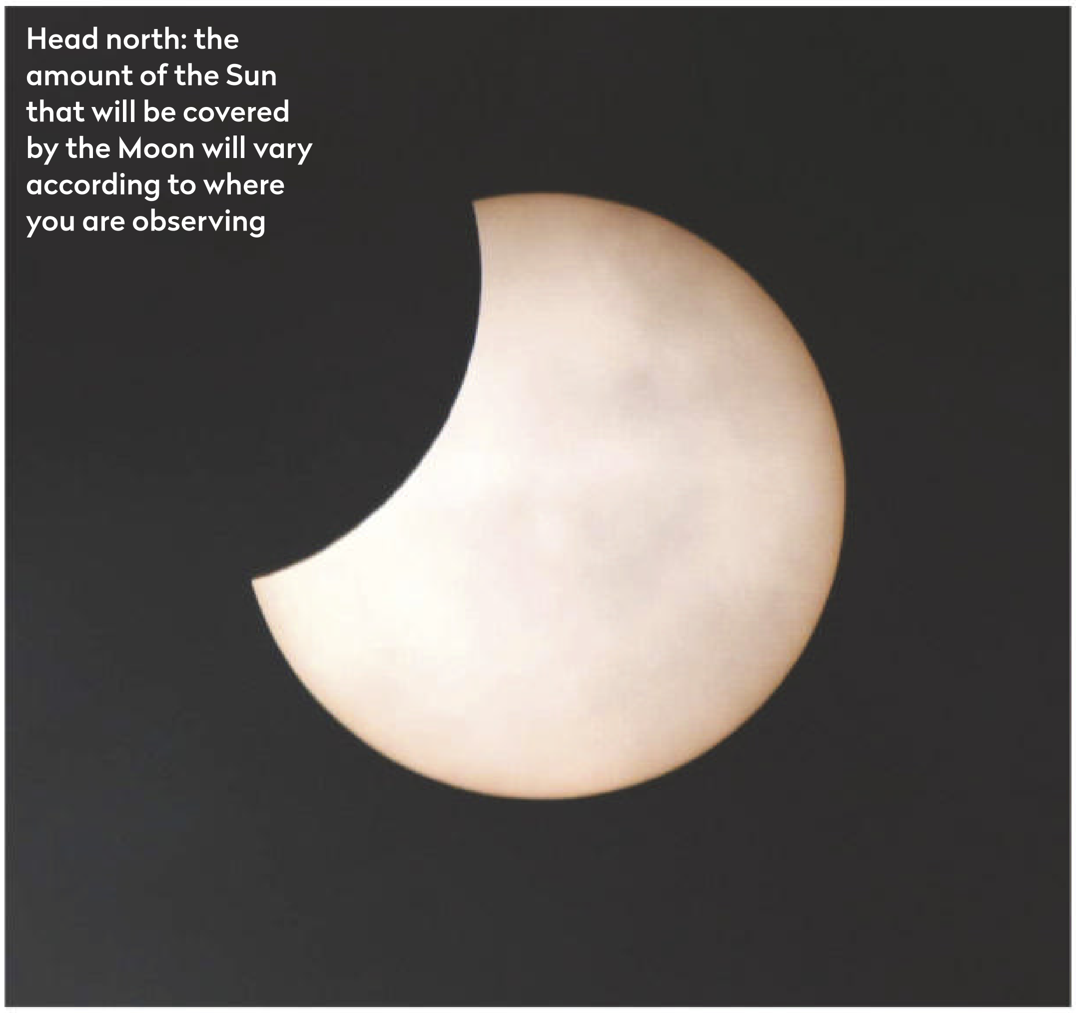
Rings of wonder: Jason's favourite image is a Saturn mosaic of 11 colour composites

CAUTION
Never look directly at the Sun with the naked eye or any unfiltered optical instrument

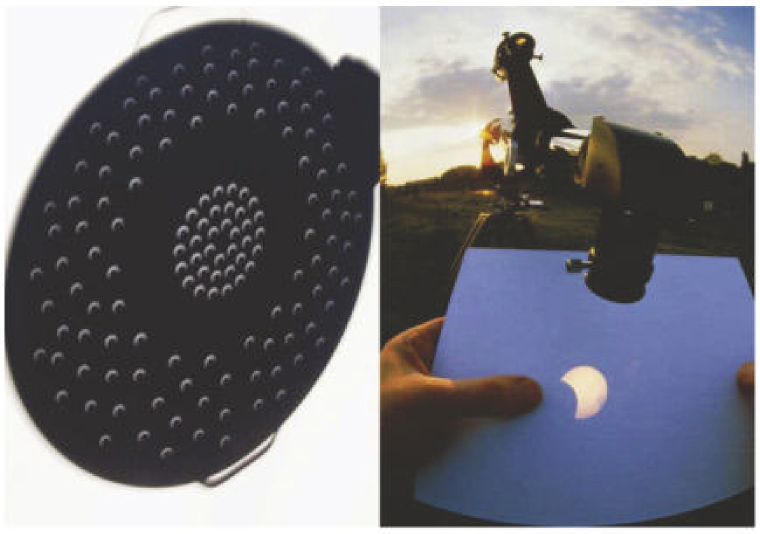
EXPLAINER

How to safely observe the partial solar eclipse

A complete guide to watching this month's eclipse from the UK, by Paul Money



Head north: the amount of the Sun that will be covered by the Moon will vary according to where you are observing



▲ **Staying safe: you can view the partial solar eclipse – without looking directly at it – by projecting it on card with a kitchen colander (left) or a refractor (right)**

There is something mesmerising about watching an event unfold that brings home the realities of our 'clockwork' Universe. On 10 June we have such an event, a partial solar eclipse that's visible from across the UK.

Whenever a solar eclipse is partial, there are usually other places on Earth where it's a total eclipse: areas in the 'path of totality' experience the night-like shadow of the Moon completely covering the Sun. But with this eclipse, nowhere will the Sun be totally covered – instead it's an 'annular' eclipse, where the Moon's shadow doesn't quite reach Earth's surface and falls a little short.

Annular eclipses come about because the Moon's orbit isn't entirely circular but elliptical, and on 8 June the Moon reaches the furthest point from Earth on its orbit – apogee – when it will appear smaller in the sky than normal. So it'll still be smaller on 10 June, the day of the eclipse. (It just so happens that the solar disc will appear slightly smaller then too: in June Earth is close to apogee in its elliptical orbit of the Sun; but even so, the Moon's small disc will still not cover it totally.)

▲ **While a partial solar eclipse is visible from the UK, a 'ring of fire' will be visible from the North Pole**

These orbital effects give rise to a ring, or annulus of light, where the outer edge of the Sun is visible even at maximum eclipse. You don't get to experience the full effects of totality, but it is still an awe-inspiring spectacle to witness, often referred to as the 'ring of fire' eclipse.

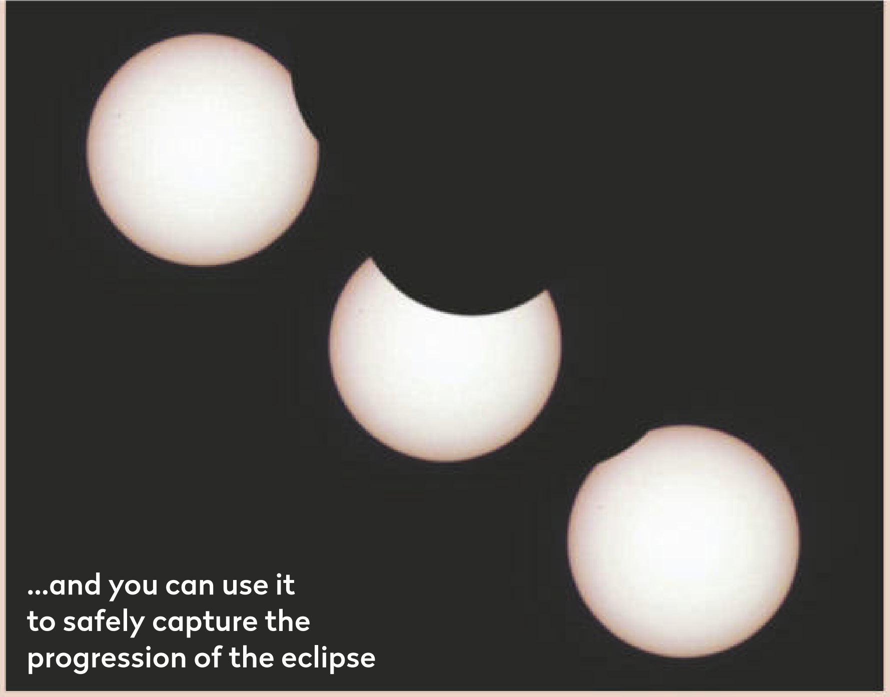
The path of annularity on 10 June is unusual, sweeping from northern Canada, across Greenland, and the North Pole (the only eclipse of the century to do so) before ending over Siberia.

Observing from the UK

Thousands of miles south of annularity, we in the UK will still get to view a decent partial eclipse. The amount of solar disc covered by the Moon depends on how far north and northwest you are. Penzance, Cornwall sees just under 22 per cent obscuration at maximum; London sees 20 per cent. Newcastle sees 28 per cent, Belfast 30 per cent, Edinburgh 31 per cent and Inverness 35 per cent. The Shetland Islands see the most coverage at 39 per cent.

STEPHEN EMERSON/ALAMY STOCK PHOTO ALL CANADA PHOTOS/ALAMY STOCK PHOTO, ROBERT COUSE-BAKER, DAVID PARKER/SCIENCE PHOTO LIBRARY, PETE LAWRENCE X 2, MAPS BY PAUL WOOTTON

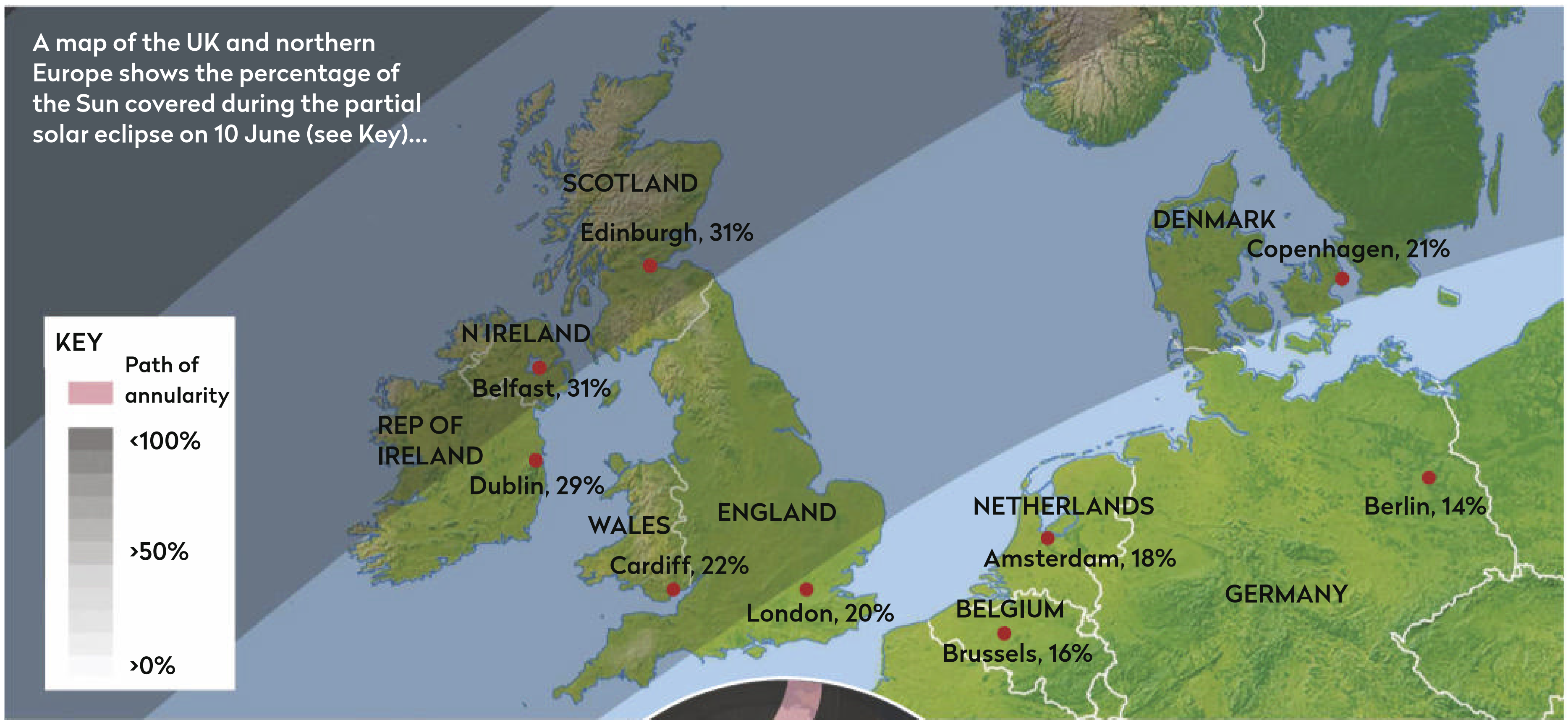

Attach a white light solar filter to the front of your telescope...


...and you can use it to safely capture the progression of the eclipse

Use a white light solar filter to image the eclipse

With a certified white light solar filter attached to the objective lens or front end of the telescope you can capture a sequence of images showing the progression of the eclipse. It is worth testing your setup on a sunny day before the event so that you can experiment with the settings you wish to use. DSLRs are ideal, especially for capturing a wide-field view of the whole solar disc and the exposures should be tested to give a good contrast for the surface. Use a sunspot group, or the limb of the solar disc to help with focusing and note the position of the focuser so that you can return to that same focus on the actual day.

Even partially eclipsed the Sun is still a bright target, so the ISO can stay low, for example ISO 100. High haze can dim the view; use a slightly higher ISO on the day depending on conditions. Exposures of 1/100 to 1/500 are worth trying; bracket your exposures until you find one that gives satisfactory results. Take a sequence of images every five to 10 minutes, and bear in mind that the whole eclipse will last over two hours.

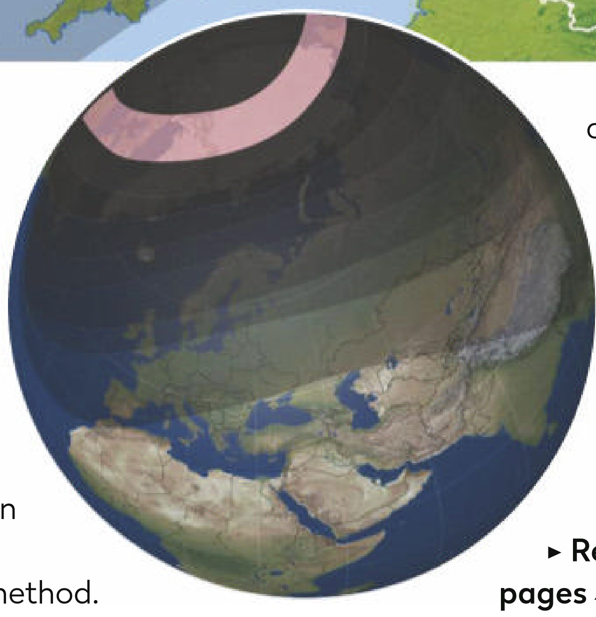


A map of the UK and northern Europe shows the percentage of the Sun covered during the partial solar eclipse on 10 June (see Key)...

Observing the Sun requires special care around safety – sunlight can seriously damage eyesight. For visual observations, use eclipse glasses, or a refractor gives a safe way of projecting an image of the Sun onto a large piece of white card. Use another piece of card fitted at the front of the tube to create a shadow zone and increase the contrast of the view. It is important that any finderscope has its caps in place and do not look through the telescope!

Another safe way is the kitchen colander method. Each of its tiny holes will project a small solar disc onto a white card, and at maximum eclipse you'll spot the notch taken out of the solar disc. You can apply the same principle by using a pinhole solar projector. White light filters (see box) can be purchased or made for your telescope for direct viewing using certified specialised solar film that cuts the light down to a safe level. You can even buy dedicated solar telescopes to view the event in a range of wavelengths, including hydrogen-alpha, calcium-K and magnesium light.

Whatever method you use, ensure you view it safely and enjoy the spectacle of our Moon passing across the Sun's disc!


▲ ...and the path of the annular 'ring of fire' eclipse (shown in pink) will sweep from Canada to Siberia

▸ **Read more about June's partial eclipse on pages 46 and page 76.**


Paul Money is an astronomy writer and broadcaster, and reviews editor for *BBC Sky at Night Magazine.*

DIY ASTRONOMY

FAMILY FRIENDLY PROJECT

Make your own Solar System mobile

Construct a home-built model to learn about our planetary neighbourhood

Going mobile: the family will enjoy making and hanging the mobile

There are few things more inspiring to the next generation of budding astronomers than having space and astronomy-themed home decor around the house. Even better is when they've been involved in the process of creating it for themselves. In this project we are using some basic materials to create a beautiful Solar System mobile that can be hung in a child's bedroom, so the wonder of space will be the first thing they see when waking up each morning and the last thing they see each night before going to sleep. It would also look great in any room in the house.

Although this is an art and craft activity, there are many learning opportunities along the way. While it is not possible to accurately replicate the relative sizes and distances of each Solar System body in such a small space, we have made sure that the planets are different sizes and they can be placed at different distances from the Sun. Each body is made from two circular pieces of card that slot together to create a three-dimensional shape. The surface features of each planet need to be drawn onto both sides of both circles before they're put together, with all four sides as closely matched as possible. This could be a great whole family activity. It is helpful to have these cardboard circles cut out before you start. The diameter of the circles we used for each planet is as follows: the Sun (15cm), Jupiter (12cm), Saturn (10cm, plus one 15cm circle for the rings), Uranus and Neptune (8.5cm), Venus, Earth and Mars (7cm), Mercury (5cm).

Mary McIntyre is an outreach astronomer and teacher of astrophotography

Get drawing

The drawing stage of this project is a great chance to learn about the visible surface of every planet in the Solar System, using photos in books or online as a reference. On the Sun, for example, we have included sunspots so you can explain what they are to family members. Meanwhile, Mercury has a rocky surface with craters similar to our Moon, while Venus has a thick atmospheric layer that obscures the surface below. Earth is a mixture of land and water and is the only planet in our Solar System to have liquid water on the surface, while Mars has a very orange-coloured surface with darker regions, as well as polar ice caps. When it comes to the gas giants, Jupiter has very interesting cloud belts and the Great Red Spot – a huge storm system that is larger than our own planet; while Saturn has subtle banding across the surface and the beautiful rings. The ice giants, Uranus and Neptune, both have subtle banding on their surface along with quite dark rings. Each Solar System body is uniquely beautiful and it's worth taking the time to reproduce their features as well as you can.

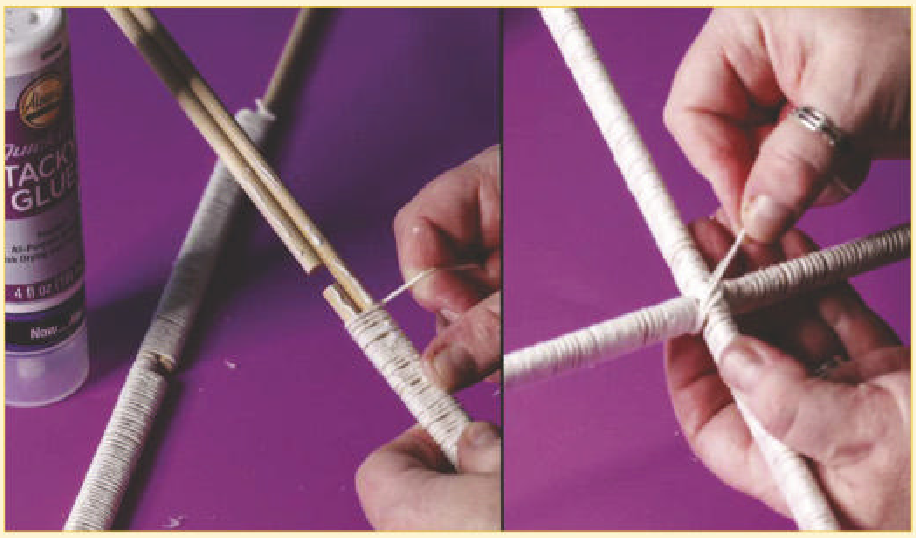
When hanging the planets, we placed them in the correct order and demonstrated the differences in axial tilt as an added point of interest.

What you'll need

- Cotton yarn or string; two 60cm-lengths of wooden dowel – we used 6mm-thick cake dowels that were 30cm-long, but we glued them together using one of the dowels as a support strut and then bound them with string.
- Two cardboard discs for each planet, plus one cardboard disc for Saturn's rings – all the planet sizes are listed above. We used 220gsm card – yellow for the Sun, white for everything else.
- Colouring pencils and felt tip pens; a ring for hanging the mobile – we used the metal ring from an old keyring.

ALL PICTURES: MARY MCINTYRE

Step by step



Step 1

For the mobile, if you need to, join your shorter dowels together to create two 60cm lengths. Lay one across the other and bind them together tightly with cotton yarn to form a big cross. This forms the structure from which the planets will hang.

Step 2

Cut two 50cm lengths of cotton yarn and thread them through the hanging ring. Tie the ends of the first length to one arm of the cross, then tie the second length to the other arm, making sure the cross is level. You can hang the mobile from the ring.

Step 3

Draw or colour in the surface features on each of your planets. Remember to cover all four sides of each planet. Draw several circles onto the disc for Saturn's rings and create divisions by colouring blocks of them in with black felt tip pens.

Step 4

On one disc of each planet cut a slit from the bottom edge to the middle, then on the other cut from the top to the middle and slot them together using a dot of glue. Cut the middle 9.5cm out of Saturn's rings and cut small notches on Saturn to fit them.

Step 5

Using a bodkin, make a hole and thread a piece of cotton yarn through the top of each planet and tie the ends. If the planet has an axial tilt, remember to make the hole the correct number of degrees down from the top.

Step 6

Tie the Sun in the centre, then place the planets in turn onto the arms of the cross, each one being a little further out from the centre, and on to the next arm. We tied them so they hung 20cm down from the arms and then trimmed the ends.

Take the perfect astrophoto with our step-by-step guide

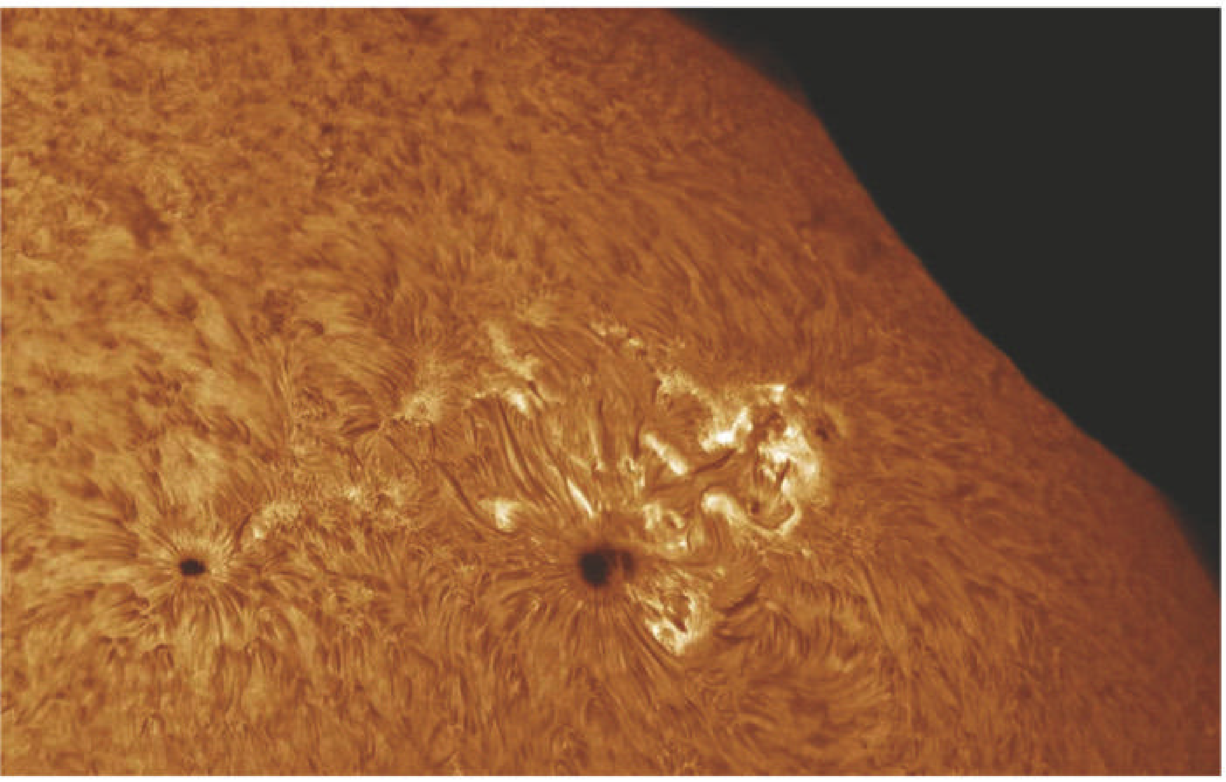
ASTROPHOTOGRAPHY

CAPTURE

CAUTION
Never observe or image the Sun with the naked eye or any unfiltered optical instrument

Imaging the partial solar eclipse

Safely capture the spectacle on 10 June in white light, hydrogen-alpha or calcium-K



▲ **Special solar filters will help you observe and catch stunning images of solar activity**

The Moon moves across the face of the Sun on 10 June, an event that varies in appearance depending on your location on Earth (see 'Explainer' on page 72). Along a narrow track running through Canada, Greenland and into Russia the Moon's disc appears to fit within the disc of the Sun to produce an annular eclipse; the 'ring of fire'.

Away from this track an ever-decreasing magnitude of partial solar eclipse will be seen until, when far enough away, the Moon will appear to miss the Sun altogether, giving no eclipse experience whatsoever.

From the UK we do get to see some of this event as a partial solar eclipse, and its those who live in the northwest who get the best seats.

Photographing the partial eclipse is an interesting project. During a total eclipse of the Sun, the time around totality allows you to take images through an unfiltered camera/lens/telescope setup, but where a partial solar eclipse is concerned, as is the case on 10 June, a certified solar filter must be used at all times.

Alternatively, the technique of solar projection can be used to show the progression of the eclipse. Here, a scope fitted with an eyepiece is pointed at the Sun, obviously without looking through it. A screen is held up to catch the bright light emitted from the eyepiece and with a bit of careful focusing, a detailed Sun image can be projected onto the screen. This image can be safely watched or captured, but there are provisos.

Projection has associated dangers; it's a technique only suitable for refractors below 5-inches (127mm) in diameter. People use reflectors to project the Sun's image, but there is a potential for damage to be caused to instruments. Enclosed optical tubes such as those found in SCTs are unsuitable for projection due to internal heating. If you do go down the projection route, never leave the setup unattended and keep everyone's eyes away from the eyepiece!

Different viewing options

A full or offset aperture white light filter allows you to view and photograph a dimmed version of the Sun safely during the eclipse. Such filters are normally bought as a sheet or roll and, after a bit of DIY, cover the front aperture of your telescope. Once you've capped or removed all finders, you're good to go.

You can also use hydrogen-alpha (Ha) or calcium-K (CaK) solar filters. These are ideal for grabbing a less conventional image. Using an Ha filter, you can check for solar prominences and it will allow you to view a 'fur-like' edge to the Sun's chromosphere known as the spicule layer. Furthermore, a magnified view of the section of limb where the Moon first makes contact or leaves the Sun's disc will allow you to catch the edge of the Moon as it crosses this strip.

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

Recommended equipment: high frame-rate camera; scope with certified solar filter; equatorial mount

▸ **Read more about June's partial eclipse on page 46 and page 72**

Send your images to:
gallery@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

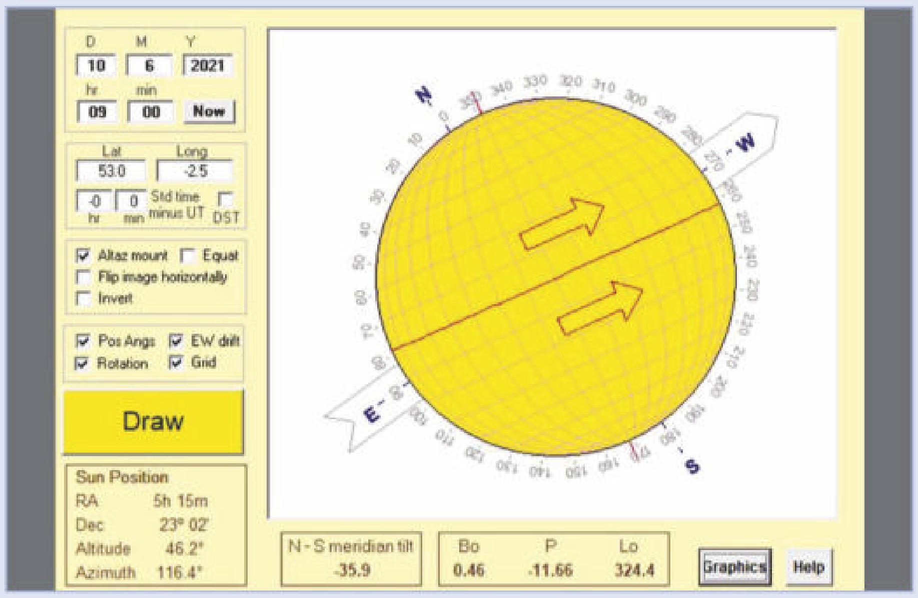
Step by step

STEP 1

Decide on the setup you want to use to image the eclipse. There are various options, including white light solar film, projection, a Herschel wedge (a special prism arrangement that allows heat to be directed away from the eyepiece), and speciality solar filters such as hydrogen-alpha (Ha) and calcium-K (CaK). It's a good idea to research how to use these methods properly *before* the eclipse.

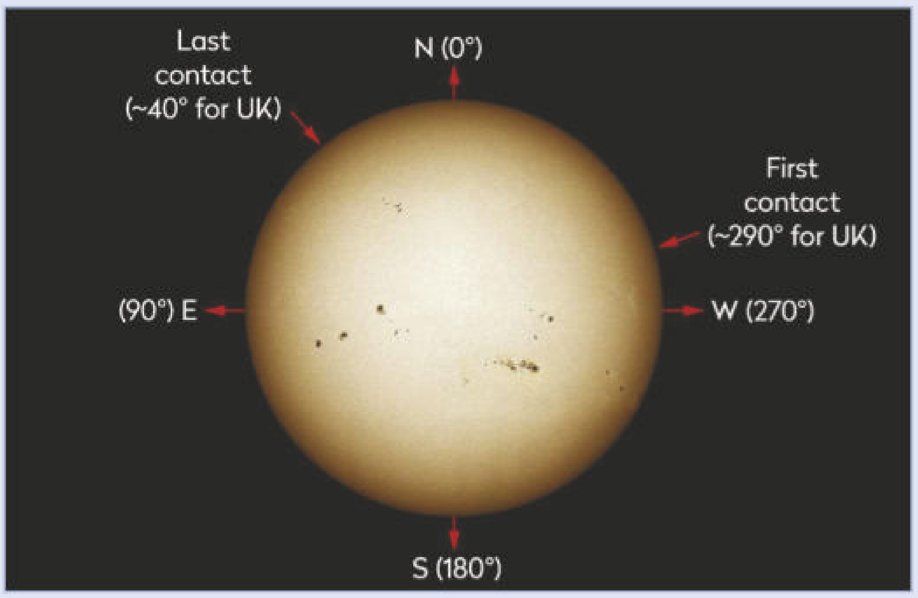
STEP 2

Select a camera; a DSLR works fine for white light, but it's less effective with Ha or CaK wavelengths. DSLR still images will be affected by prevailing seeing, the effects worsening with increased image scale. A mono high frame rate camera gives crisp results, but captures need to be short to avoid blurring from lunar motion.



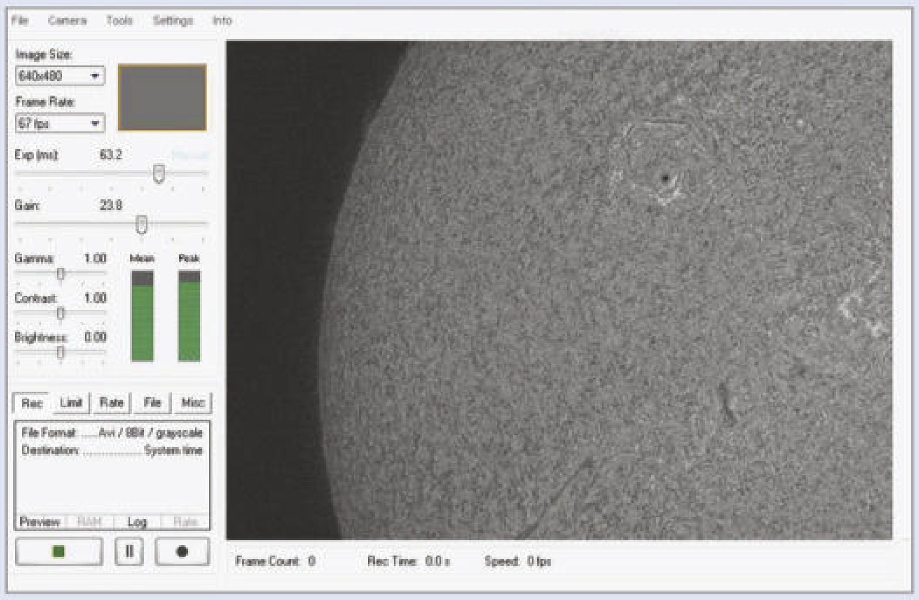
STEP 3

Get to know the view orientation to catch the beginning of the eclipse (first contact) at high image scale. Equatorial mounts are easiest for this, but it also can be worked out for altaz mounted equipment. The free software Tilting Sun (**atoptics.co.uk/tiltsun.htm**) shows how different mounts will affect the view of the Sun.



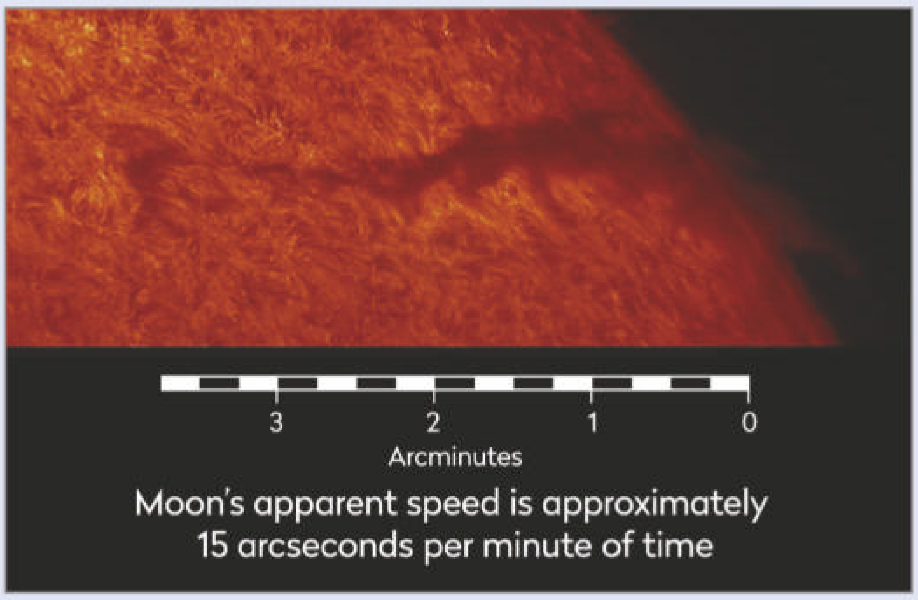
STEP 4

For equatorial mounts, moving a telescope south in declination means the last edge of the Sun visible is the southern limb. Slewing east in RA, the last edge visible is the eastern limb. The position-angle measures the number of degrees from north (0°) travelling east (90°), south being 180°, west 270°. First contact occurs at 290º.



STEP 5

If you're using an equatorial mount, set it up on nights before the eclipse to ensure accurate polar alignment. Also, practise solar imaging in the run-up to 10 June. Using control software, ensure your high frame rate camera's exposure level isn't saturated, but 80–90 per cent peak. Aim for a rate of over 60 frames per second.



STEP 6

Set up early, say from 09:00 BST (08:00 UT). If using hydrogen-alpha equipment, remember first contact will occur a bit earlier than for white light due to prominences/spicules along the Moon's path. Keep capture sequences short, say 10–30". For the time of first contact see **timeanddate.com/eclipse/map/2021-june-10**.

ASTROPHOTOGRAPHY PROCESSING

How to improve images of low astro targets

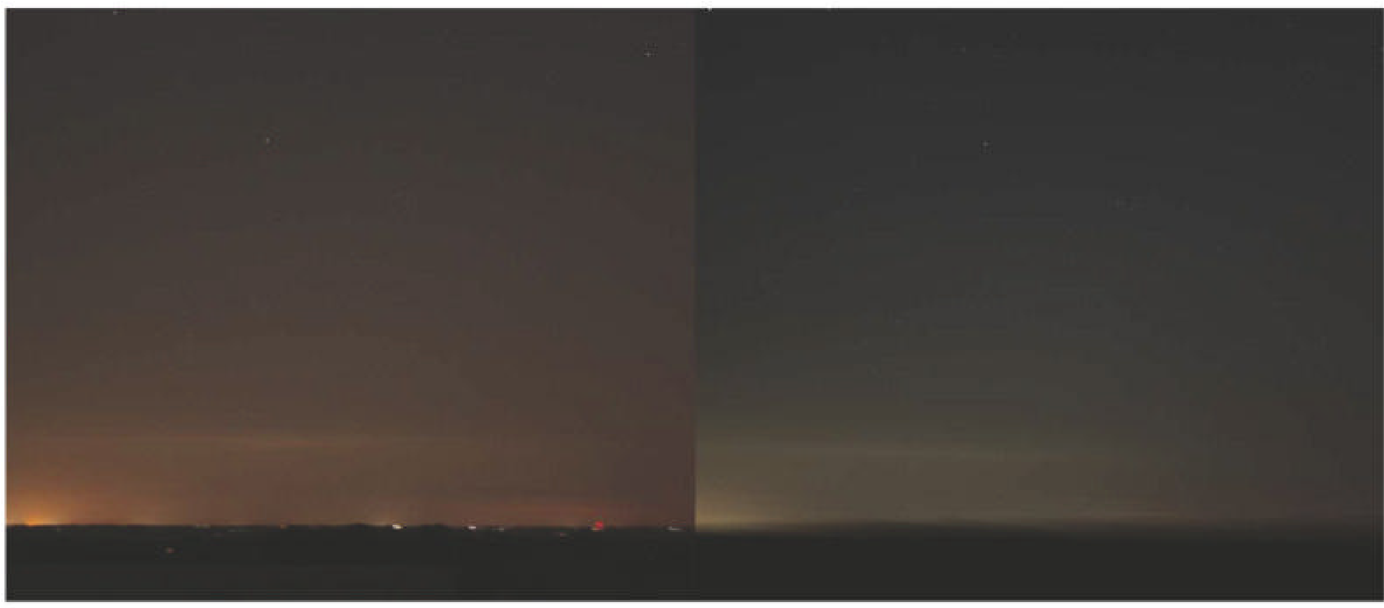
Use photo-editing software to remove haze and bring out starry details

◄ **After processing, our final image reveals the details of M6 and M7**

Sometimes we love an astrophotography challenge. One summer evening, while we were at a 'relatively' dark site, we realised that the star clusters M6 and M7 were low in the south and the sky was fairly clear – almost down to the horizon. Normally, photos of deep-sky targets so low down have a poor appearance, due to haze and the thicker cross-section of atmosphere they are being viewed through, but it piqued our interest to see if we could improve the images taken of them so low.

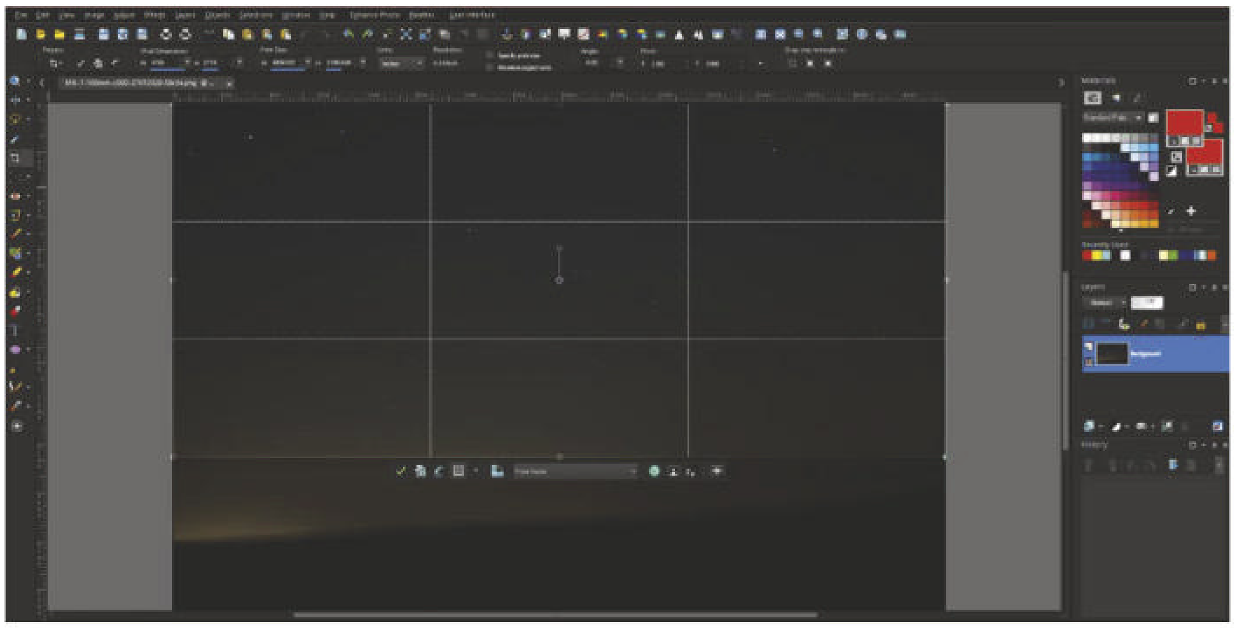
Using a tracking mount and a camera with a 100–400mm zoom lens set at 100mm and f/4.5, we took a set of 34x 20-second exposures at ISO 1000 to see if the clusters could be imaged reasonably well while being so low. They could barely be seen on the RAW images, due to that thicker amount of atmosphere we were imaging through and the haze. However, it was possible to bring out the detail of both clusters against the hazy view by stacking the images and doing a little image-processing magic, and the final result (left) surpassed our expectations. In this article we explain how to achieve this.

First, we took the set of 34 images and stacked them (you can use your favourite stacking program). We used Astro Pixel Processor (APP) to produce the initial stacked image (see below) ready for processing. Because of the background calibration in APP, it produced a slightly greener image and, as it was stacked on the stars, the horizon naturally became smeared out, along with the low bank of

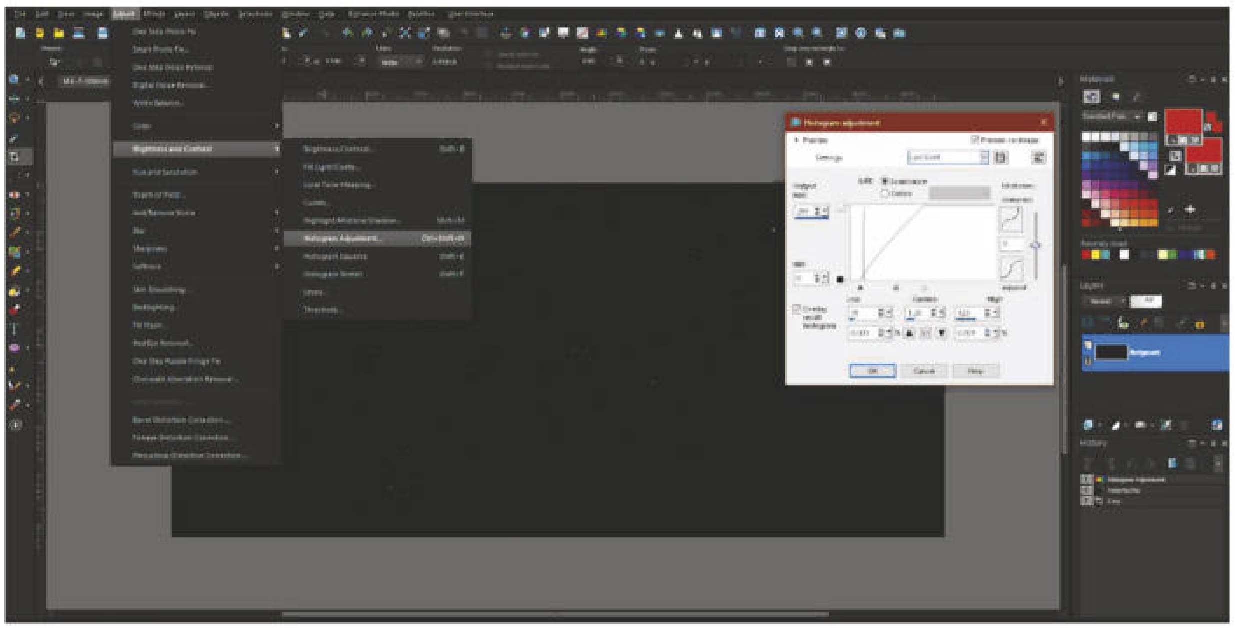


▲ **Contrasting views: M6 and M7 are barely visible in the initial RAW image (left); while a stacked image (right) shows a little more detail, but with a smeared-out foreground**

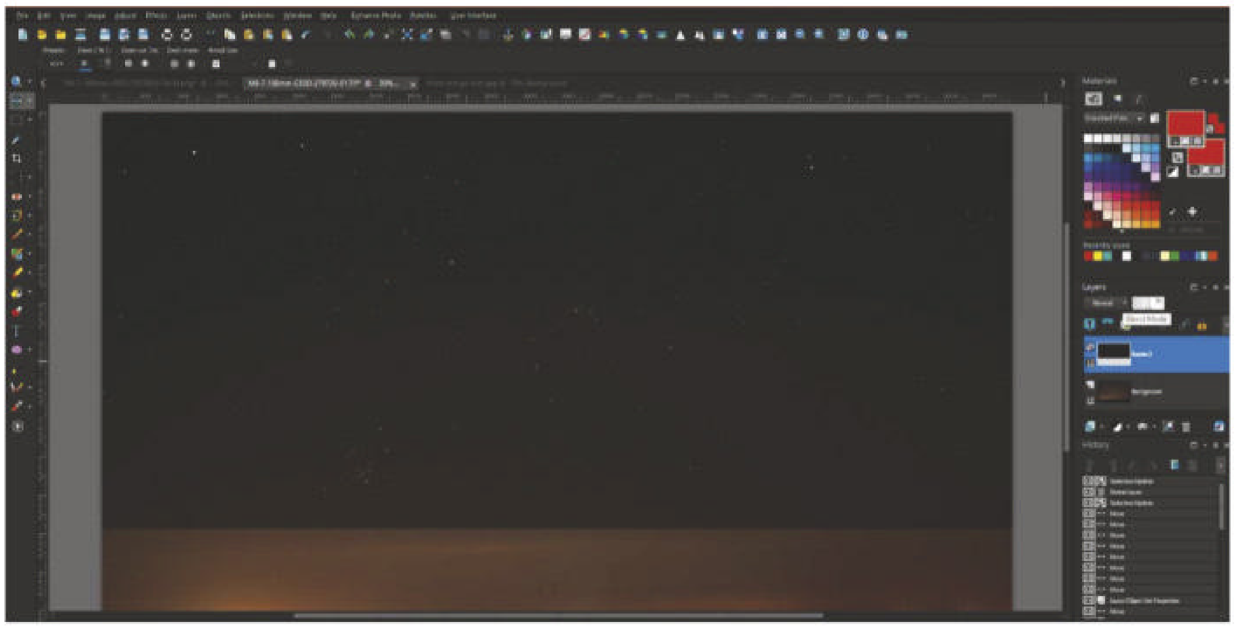
ALL PICTURES: PAUL MONEY



▲ **Screenshot 1: crop the area to be processed, while excluding the horizon and lower haze**



▲ **Screenshot 2: use 'Histogram Adjustment' on the cropped image**



▲ **Screenshot 3: the cropped image is pasted as a layer overlying an original exposure**

haze. This doesn't matter, however, as it's something that post-processing can fix.

Get ready to crop

So, by using photo-editing software, in our case PaintShop Pro 2019, we clicked 'File › Open' and found the stacked image file we saved from APP for editing. Using the 'Crop' tool, we selected the majority of the image, excluding the lower haze and horizon (see Screenshot 1). We then double-clicked within that area to automatically crop to that selection. Because the haze band wasn't too bad we did a simple crop, but you can use a point-to-point selection if you want more control over what is selected for cropping.

The next step can be done in one of two ways. You can either use the AstroFlat plug-in, if you have it installed, to remove the gradient across the image or, as in our example here, you can use the 'Histogram Adjustment' tool to adjust the black point to decrease the effect of the gradient, while sliding the middle slider to the right and bringing the white point slider in a little too (see Screenshot 2). Remember, adjust to your own taste, but don't overdo it. Then click 'OK' to perform the adjustment.

Our image shows the stars well and, in theory, we could leave it there, but we can merge this image with one of our original single exposures to bring back the haze and horizon for an atmospheric effect (see Screenshot 3). To do this we chose the first image of the sequence and opened it as a new one in a separate tab. Next, we clicked on the earlier cropped image tab, and from the main menu chose 'Edit › Copy' to copy it to the clipboard. Next, we clicked on the unprocessed initial image, selecting 'Edit › Paste' as a new layer. The new layer's properties were set to 50 per cent so the stars were visible in both images. We then nudged the cropped image layer until the stars were aligned.

Once happy with the alignment we put the cropped image layer back to 100 per cent and set the 'Blend Mode' to 'Lighten' in the 'Layers' properties. This shows the cropped layer with the enhanced stars along with the underlying original image. If it's done well it can still look natural, as if the sky was clear almost to the horizon.

Clicking 'Layers › Merge › Merge all' to flatten the layers into one image, we finally saved our processed image. The result is an enhanced view of the stars, bringing out both star clusters nicely along with the horizon too.

3 QUICK TIPS

1. Try to pick a night that has the best seeing conditions as low to the horizon as possible.

2. For a more accurate crop use the point-to-point selection tool.

3. Take small steps when adjusting the histogram of the cropped image so as not to overprocess it.

Paul Money is an astronomy writer and broadcaster, and is reviews editor for *BBC Sky at Night Magazine*

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

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◁ Moon

Rich Addis, Wallasey, Merseyside, 21 March 2021

Rich says: "This half Moon was the highest of the year and I didn't want to miss the opportunity once the clouds had cleared. The air was so still and crisp, so I set out to shoot close-up panels. The image is 12 panels, each of 640 frames stacked, and then the panels stitched together manually in Photoshop."

Equipment: ZWO ASI 120MC colour camera, Celestron NexStar 6SE Schmidt-Cassegrain
Exposure: 2.70ms, gain 50
Software: FireCapture, AutoStakkert!, Lightroom, Photoshop

Rich's top tips: "I prefer to shoot close-up detail and move around the surface capturing each area separately. This allows sharper detail and better focus, but it can be easy to miss a patch. When making a mosaic image like this, make sure you zig–zag your way around the surface and give plenty of overlap between each panel. You'll need to recognise certain features to make sure you have that area covered. Try not to shoot when there is thin cloud passing, because the exposure will be different between panels, making them hard to stitch. Lastly, wait until the Moon is at its peak: the higher the better for a clearer view."

◁ Rho Ophiuchi

Richard Leighton, via Chilescope, Ovalle, Chile, May 2020

Richard says: "The spectacular colours of nebulae, vast dust lanes, and the views of globular clusters and Antares make the area around Rho Ophiuchi one of my favourite regions of the whole Milky Way to image."

Equipment: FLI MicroLine 16200 CCD camera, Nikon 200mm f/2 lens, 10 Micron GM1000 HPS mount **Exposure:** L 18x 300", Ha 18x 300", RGB 6x 300" each **Software:** PixInsight, Photoshop

△ ISS close-up

Gabor Sagi, Witney, Oxfordshire, 29 September 2020

Gabor says: "I was lucky because it was a cloudy day and I only saw 5–6 seconds of the ISS's flyby, exactly at the time of maximum elevation."

Equipment: ZWO ASI 224MC colour camera, Sky-Watcher Skymax-127 Maksutov-Cassegrain, Sky-Watcher AZ-GTi mount
Exposure: 0.850ms, gain 195
Software: FireCapture, PIPP, Photoshop

▽ Bode's Galaxy and the Cigar Galaxy

Craig Ogier, Minehead, Somerset, 16 and 17 March 2021

Craig says: "This was the longest I'd spent on one image and I can really see the benefit in obtaining as much integration time as possible. I love these galaxies and the way the hydrogen-alpha shows through red using a dual bandpass filter."

Equipment: ZWO ASI 1600MC camera, Sky-Watcher Explorer 200P reflector, Sky-Watcher EQ6R-Pro mount **Exposure:** 15 hours 8 minutes total **Software:** DeepSkyStacker, Photoshop

△ Zodiacal Light

Joshua Rhoades, Mason County, Illinois, USA, 7 March 2021

Joshua says: "On this night the Zodiacal Light was visible on the western horizon, with Mars and the Pleiades encompassed by the pillar of light."

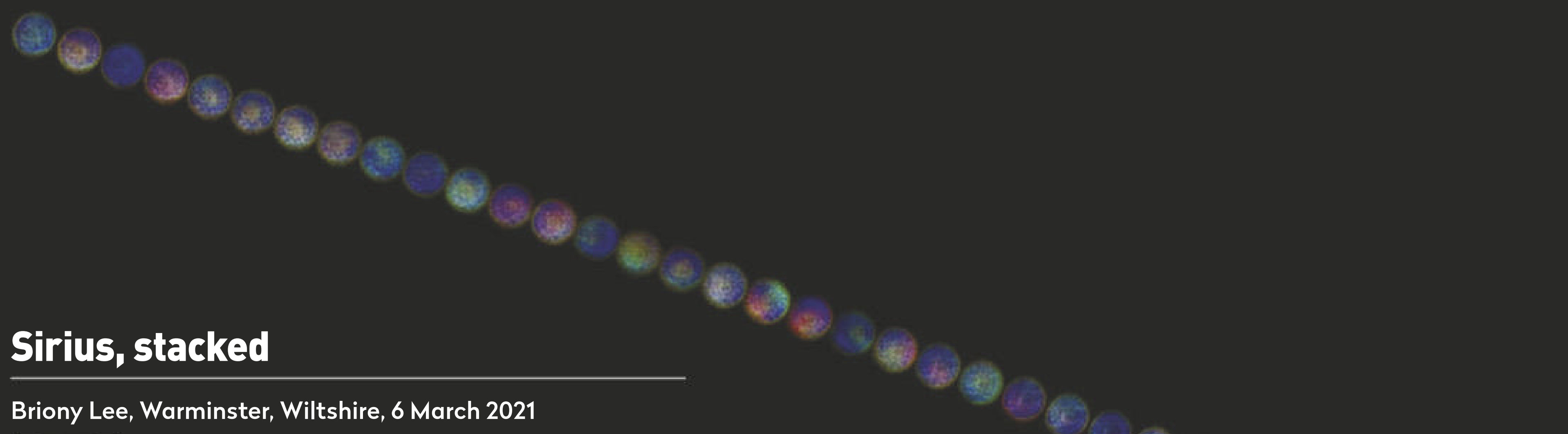
Equipment: Canon EOS 5D Mark IV DSLR, Irix 15mm lens, Sky-Watcher Star Adventurer **Exposure:** sky ISO 800 f/4, 8x 60"; foreground ISO 800 f/4, 120" **Software:** Photoshop

The Orion and Running Man Nebulae ▷

Ed Holt, Bassingbourn, Cambridgeshire, 30 January 2021

Ed says: "This high dynamic range image is a blend of 10", 60" and 180" exposures, to keep the detail in the bright Trapezium core region and highlight the fainter outer nebulosity."

Equipment: Canon 60D DSLR, Sky-Watcher Evostar 80ED apo refractor, Celestron CG-5 GT mount **Exposure:** ISO 400, 5h total **Software:** NINA, DeepSkyStacker, Photoshop



Sirius, stacked

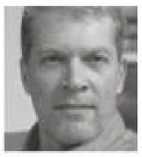
Briony Lee, Warminster, Wiltshire, 6 March 2021

Briony says: "After seeing the article ['Processing', March 2021 issue, page 78] about photographing defocused Sirius, I had a go. It's the first time I've attempted it and I couldn't believe the outcome!"

Equipment: Canon EOS 2000D DSLR, Tamron 70–300 lens, Velbon Sherpa 750R tripod Exposure: ISO 200 f/4.5, 1" each, 36 frames, 40" apart Software: StarStaX

▽ Albireo

Kfir Simon, via Tivoli Astro Farm, Namibia, 20 June 2020



Kfir says: "Albireo was always on my 'to do' list. When it was near its zenith, Tivoli Farm gave me the perfect opportunity. Finally, mission accomplished!"

Equipment: FLI ProLine 16803 CCD camera, Phillip Keller 16-inch Hypergraph, ASA DDM 85 mount Exposure: L 10x 60", RGB 10' each Software: MaxImDL, Photoshop

ISS crossing the Moon ▷

James Grandfield, Dublin, 24 March 2021

James says: "This was a shot I was looking to get for over two years as the timing, equipment and weather all had to be perfect. I was lucky, and with clear skies I drove to the Phoenix Park and with timing down to the split second, I took a burst of photos."

Equipment: Nikon D500 DSLR, Nikon 200–500mm lens
Exposure: ISO 640 f/7.1, 1/250" Software: Snapseed

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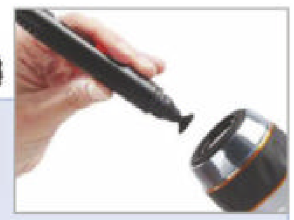

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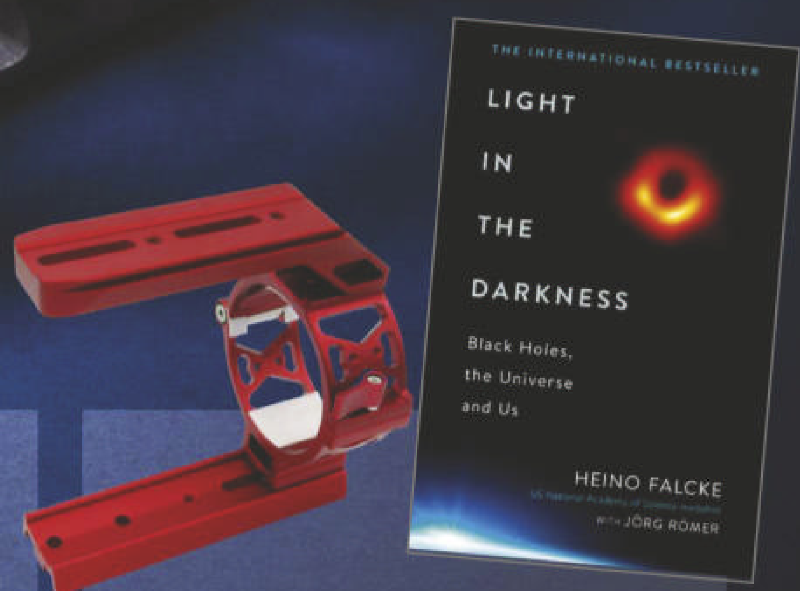
86
We put the Altair Hypercam 115M mono TEC cooled CMOS camera through its paces



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HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

PLUS: Books on capturing the iconic M87 black hole image and time travel, plus a look at must-have astronomy gear

Altair Hypercam 115M Mono TEC cooled CMOS camera

A monochrome camera that excels as an all-round performer

WORDS: TIM JARDINE

VITAL STATS

- **Price** £1,350
- **Sensor** Sony IMX492 Monochrome CMOS
- **Exposure duration** 0.1ms (0.0001 seconds) up to 1,000 seconds (Trigger mode)
- **Resolution in pixels** 4128 x 2808
- **Region of interest** Yes
- **USB port and cable** USB 3.0, 1.8m cable (USB 2.0 also supported)
- **Power supply** 12V DC
- **Size** 105mm x 85mm
- **Weight** 580g
- **Supplier** Altair Astro
- **Tel** 01263 731 505
- **www.** altairastro.com

The world of astronomical cameras is fast paced and Altair Astro has just released a new model, the Hypercam 115M, a monochrome CMOS camera with thermoelectric (TEC) cooling.

The Hypercam 115M takes grayscale images, requiring separate filters and additional processing to produce pictures with colour. Although the camera itself is not that difficult to use, the initial learning curve – and extra equipment needed to use with it – will perhaps make it more desirable to those with a determination to pursue astrophotography seriously, rather than beginners with a casual interest in taking snapshots of the night sky.

The sensor and pixel size of the Altair Hypercam 115M are best matched with a medium to longer focal length telescope, so we chose our 150mm, f/7 refractor, a Sky-Watcher Esprit 150ED, and a filter wheel using 2-inch filters. The camera is a reassuringly solid piece of kit and weighs over half a kilogram, and there is ample M42 x 0.75mm female thread at the front to ensure a connection to other equipment.

Before connecting the camera to our laptop we installed the AltairCapture software, which is included on a CD, although downloads can provide the latest version. A new version of the ASCOM driver – ASCOM is an industry-standard interface that allows different pieces of astronomical equipment to communicate – became available for the camera during our review period. This improved the camera's stability while the large image files are downloading. We tried using the Hypercam 115M with our own imaging software and the ASCOM driver, but we found that some functionality was unavailable. Thankfully, Altair supplies its own software with full functionality.

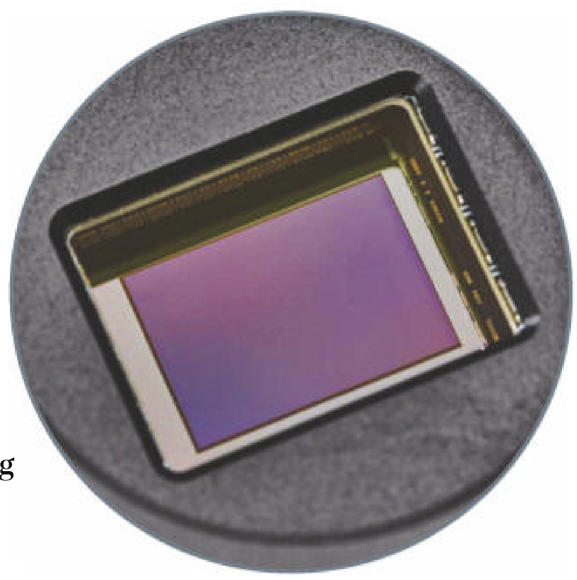
Versatile settings

Once the camera was running, with the cooling system set to –10°C, we started experimenting with exposure lengths and gain settings on some deep-sky objects. The 14-bit CMOS sensor provides a wide range of settings, which enabled us to adapt to the sky and Moon conditions on a dynamic basis – by quickly changing settings. We used our hydrogen-alpha (Hα) filter and higher gain settings to capture faint emission nebulosity, and a lower gain setting for galaxies and globular clusters, which resulted in very smooth, low-noise images. With the range of filters ▸

A capable sensor

The key to the versatility and range of the Hypercam 115M is the CMOS sensor at its heart, a Sony IMX492. It is a 4/3 size unit, measuring 23.2mm across the diagonal. At full resolution it would yield a 47MP image from its tiny pixels, but this wouldn't be much use for astronomy purposes. By using a process called binning, four of these micro pixels are combined together to work as one very sensitive unit, producing excellent response for astrophotography use in an 11.6-megapixel file.

The sensor is especially capable in low light applications, having both the STARVIS and Exmor-R trademarks from Sony. The Exmor-R rating refers to the sensor's increased sensitivity with low noise characteristics, something that makes these sensors desirable for long exposure photography, while the STARVIS label refers to back-illuminated pixel technology designed for high-quality surveillance imaging, especially in the dark, which is perfect for our requirements.



ALL PICTURES: @THESHED/PHOTOSTUDIO

Heated optical window

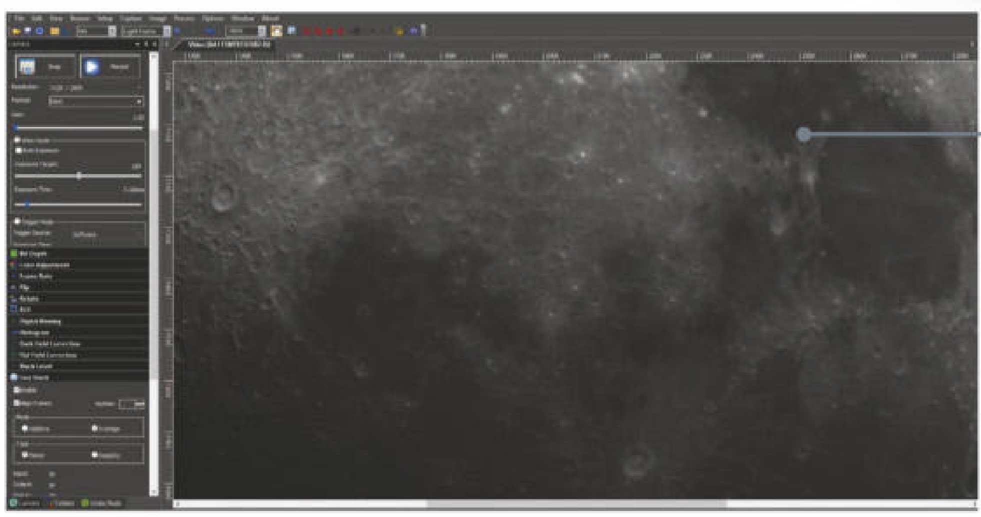
With very low temperatures possible inside the camera body, there is a risk of dew forming on the outside of the optical window. The window is surrounded by tiny heating elements, which are controllable in AltairCapture. By gently warming the optical window, issues with dew spots are avoidable.

Thermoelectric cooling

The body of the camera is designed to dissipate heat produced by the imaging process, with a quiet fan efficiently pulling air through the heat sink. In addition, the powered active cooling system allows direct control of the camera temperature down to –40°C below ambient, for fully matched light and dark frames.

USB – capabilities and hub

The Hypercam 115M is a USB 3.0 camera, but it's fully controllable via USB 2.0. On the rear of the camera there are two USB 2.0 ports which may be useful for using short cables to connect simple, low demand accessories like a filter wheel.



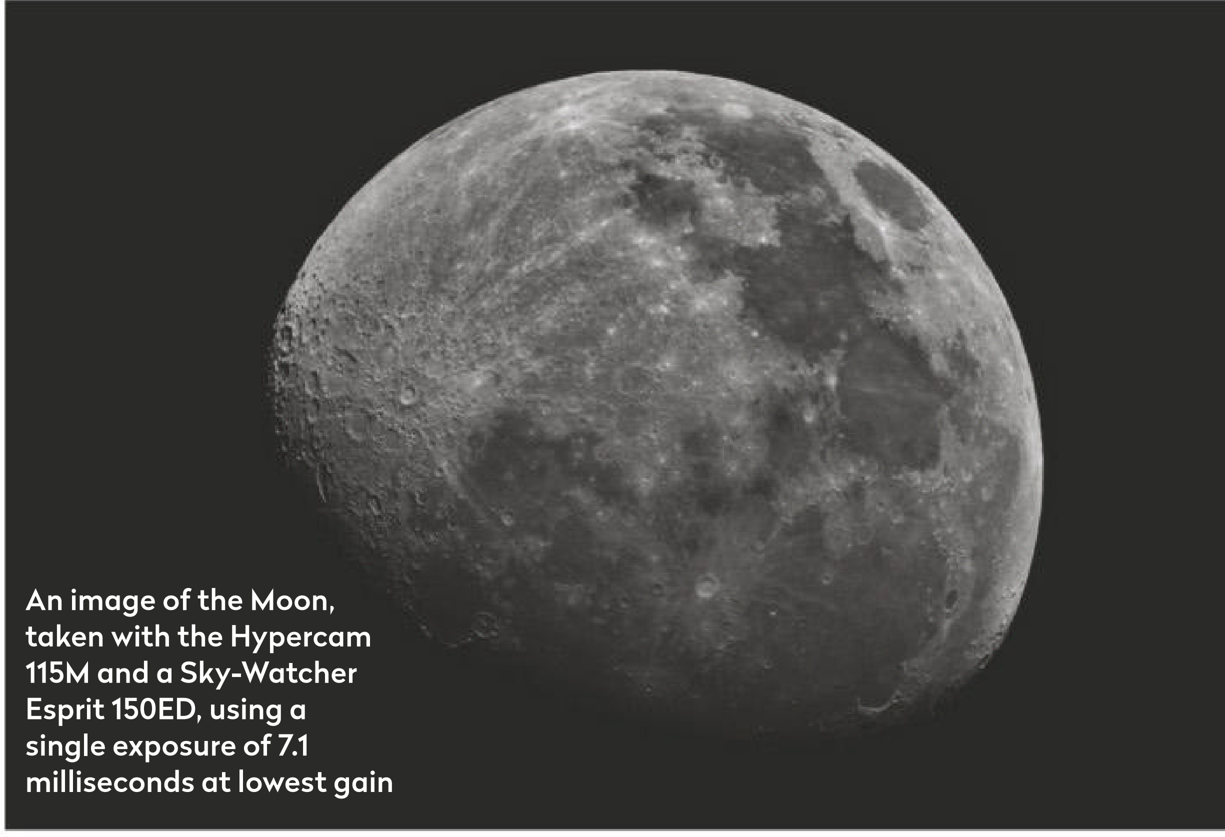
AltairCapture software

The free software provided to operate the camera is simple to learn, easy to use, and allows total control of the camera, and TEC system, and adds useful elements to the usability of the camera. For instance, 'Live stacking' mode builds images up from individual exposures as they download.

FIRST LIGHT

Armoured case

The Hypercam 115M is supplied with a rigid ABS-style protective plastic case with foam padding. It holds the camera and the accompanying accessories, plus a 2-inch nosepiece, a dew control canister, a 12V power supply, a software disc and USB 3.0 cable.



An image of the Moon, taken with the Hypercam 115M and a Sky-Watcher Esprit 150ED, using a single exposure of 7.1 milliseconds at lowest gain

◂ The Great Globular Cluster, M13, taken with the same setup using a hydrogen-alpha (Hα) filter – with 2 hours and 5 minutes of 2' 30" exposures, plus 30 minutes each using Red, Green and Blue filters with 1' 30" exposures

◂ The Horsehead Nebula, taken with the same setup in hydrogen-alpha – with 45 minutes of 5' exposures

▸ and exposure variations available, we are convinced that no matter the type or brightness of any particular deep-sky target, the Hypercam 115M can be configured to capture it to a high standard.

Our targets of choice were the Leo Triplet of galaxies, the Great Cluster in Hercules, M13, plus (using our narrowband filter) the open cluster NGC 2244 at the Rosette Nebula's centre, and the Horsehead Nebula. One thing to note was that the relatively large file sizes soon started filling up our hard drive, especially when we were taking four sets of images for each target, using Luminance, Red, Green and Blue filters. These files require a robust PC or laptop to process them.

The camera can also be used for on-the-fly image grabbing, which is real time image capture and stacking using the 'Live stacking' function in AltairCapture. With region of interest imaging, a smaller area of the sensor can be used, which enables much higher frame rates to be captured, making the camera attractive for lunar and solar imaging too. Conditions did not allow us to test this aspect with a live target, but on the bench we selected a 640 x 480 region of interest and noted that the camera was running at 72fps over USB 3.0, demonstrating that the 115M could also produce good quality planetary, lunar, and solar images, making it an all-round performer.

As is common with this type of CMOS camera, long exposures may produce glow artefacts on image edges and a starburst effect. To negate this we took a series of dark frames – exposures with the lens cap on using the same settings as the actual images – and applied them in the stacking process.

With a good-sized sensor, a wide range of sensitivity adjustment and fine-tuning options, the Hypercam 115M looks set to become the monochrome camera of choice for dedicated astrophotographers.

VERDICT

Build & design	★★★★☆
Connectivity	★★★★½
Ease of use	★★★★☆
Features	★★★★½
Imaging quality	★★★★½
OVERALL	★★★★½

KIT TO ADD

1. Altair 2-inch narrowband filter set

2. Altair 125mm EDF APO

3. Altair Planostar 0.8x reducer

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Our experts review the latest kit

FIRST LIGHT

Omegon MightyMak 60 Mini Dobsonian telescope

A highly portable scope that's tailored to astronomy newcomers

WORDS: CHARLOTTE DANIELS

VITAL STATS

- **Price** £129
- **Optics** 60mm Maksutov-Cassegrain
- **Focal length** 700mm
- **Focal ratio** f/11.7
- **Mount** Dobsonian single-arm or table-top tripod
- **Extras** Red dot finder, 25mm 1.25-inch eyepiece, star diagonal, carry bag
- **Weight** 650g (with tripod) or 1.9kg (with Dobsonian mount)
- **Supplier** Rother Valley Optics
- **Tel** 01909 774521
- **www.** rothervalleyoptics.co.uk

For budding astronomers, the first telescope needs to be simple to set up and affordable, while the chosen kit also needs to be rewarding to use. These are difficult qualities to balance, however, and Omegon's MightyMak 60 Mini Dobsonian tries hard to deliver all three. We were impressed to discover the MightyMak 60 comes with two mount options; a table-top tripod and a mini Dobsonian mount. The tripod arrives in a smart carry bag that also contains the MightyMak, a red dot finder, a star diagonal and an eyepiece. Despite this, the bag is surprisingly light and no bigger than your average wash bag; this telescope is certainly not going to clutter up the room it is stored in.

Smart appearance

The overall look is smart, and the main elements appear well made. For example, the Dobsonian mount feels solid, while the tripod and all the mounting points on the tube are metal. Each mount is reasonably stable considering their size. The accessories are plastic, which is to be expected at this level. Setting up the MightyMak could not be easier; fix the tube to either mount via the Vixen dovetail; pop in the finder, diagonal and eyepiece and you're ready to go. If there's any doubt, the instruction booklet provides clear instructions for beginners.

Of the two mounts, we felt the Dobsonian is better suited to stargazing as it's more flexible for viewing overhead objects. However, because the table-top tripod fits nicely into the bag it is a decent, compact option if walking to a dark-sky site.

We performed a basic star test and found the MightyMak arrived well collimated – which is good because collimating Maksutovs can be tricky. The telescope's focus knob gave just the right amount of resistance required. We swung over to the Moon and while adjusting the focus, it stayed firm and central in the field of view. 'Image shift' is a common issue with Maksutovs, so we were pleasantly surprised to see that this didn't happen while focusing the MightyMak 60. ▸

Maksutov design

The fact that Omegon's mini Dobsonian is a Maksutov-Cassegrain is a big plus; its compact optical system means that you get a longer focal length than a regular Newtonian tabletop telescope of the same aperture.

Indeed, the MightyMak 60 gives beginners access to a punchy 700mm focal length from an aluminium tube that's only 200mm long. This focal length is a little less than other Maksutovs of similar aperture, but the fact that the scope, tripod and accessories can all fit into a carry bag no larger than a shoebox is impressive and exceeds the definition of portable.

Another bonus is that Maksutov collimation is designed to last; if collimated correctly you don't need to perform the complex process of aligning optics often, unless the scope gets bumped around in transit.

The MightMak's design is beautifully simple, from the 'open and shut' hinged dust cap down to the focus knob. The optical tube assembly (OTA) is sleek and uncomplicated but looks good, and it's this simplicity that makes Omegon's mini Dobsonian accessible for beginners of all ages.

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Dobsonian mount

The wooden altaz mount is the most suitable of the two mount options for astronomy. It is robust and has smooth motion, allowing for small adjustments while lining up a target. The altitude adjustment knob is large and easy to rotate, which is handy for dark, cold nights or gloved hands.

Red dot finder

The red dot finder is an ideal accessory for entry-level telescopes because it is easy to use and helps beginners to locate more obvious targets. This makes it a great aid for finding and viewing planets, which Maksutov telescopes are built for. The finder has a standard foot for easy attachment.

Threaded visual back

The Maksutov's built-in T2 thread is an excellent feature for photographers; as this allows the direct attachment of a DSLR to the tube's visual back, when the camera is fitted with a T-ring adaptor. A 1.25-inch extension is not required for the connection, which reduces the risk of the camera slipping and falling.

FIRST LIGHT

Vixen Dovetail

The MightyMak is fitted with a Vixen-style dovetail bar, which also has ¼-inch tripod threads built-in. This design allows it to be mounted to almost all photography and astronomy mounts; the tube can be used on a star tracker, for instance, for those wishing to upgrade their mount or to pursue astrophotography.

KIT TO ADD

1. RVO 1.25-inch 2x Barlow lens with T thread
2. RVO 1.25-inch ND96 Moon filter
3. Antares dual beam red/white variable torch

▸ We felt the optics were reasonable for a starter telescope: there was no noticeable colour fringing while observing the half Moon, and the supplied 25mm Kellner eyepiece achieved a lovely crisp image of this object. When we tested it, we found the MightyMak 60 reduces chromatic aberration – an effect usually seen as unwanted coloured rings around brighter objects – as expected. We swung over to Sirius (Alpha (α) Canis Majoris) and Betelgeuse (Alpha (α) Orionis), noting some distortion of the stars at the edge of the field of view. Being picky, we found that the overall image provided by the MightyMak 60 was quite dim; despite decent seeing conditions, only the most distinct objects were bright. We looked at the Orion Nebula, M42, and while we could find and view it, we were unable to resolve any detail.

This telescope performs best at viewing the Moon and planets, and would benefit from either a Barlow lens or a slightly more high-powered eyepiece added to the kit. Without these accessories you'll find that objects will appear small, which regrettably reduces the visual impact for beginners. For example, the supplied 25mm eyepiece only offers 28x magnification and made us hungry for more power. We did pop a 15mm and then a 9mm eyepiece in, and found the Moon stayed clear at 15mm, but at 9mm the focus was much less sharp: the 77x magnification given by the 9mm eyepiece pushed the optics a little too far – falling short of the 118x magnification a telescope of this aperture is theoretically capable of.

The MightyMak 60 has extra strings to its bow, however, because it can also serve as a telephoto lens. It is lightweight and comes with the necessary threads to attach a DSLR camera and fix it to a standard full-size photography tripod. It would therefore make a good spotting scope if you decided to upgrade your astronomical telescope.

New astronomers need a scope that is easy to set up and reliable enough to encourage their curiosity. And while the MightyMak 60 is an adaptable, good looking, ultra-portable setup that ticks plenty of boxes, its optics could leave more of an impression.

Table tripod

Omegon provides a highly portable photography tripod, which is designed to fit into the carry bag alongside the telescope, eyepiece and diagonal for a light and convenient travel option. As the MightyMak is effectively a lightweight telephoto lens, the tripod offers potential for a great daytime photography setup too.

VERDICT

Assembly	★★★★☆
Build & design	★★★★☆
Ease of use	★★★★½
Features	★★★☆☆
Optics	★★★☆☆
OVERALL	★★★½☆

ALL PICTURES: @THESHED/PHOTOSTUDIO

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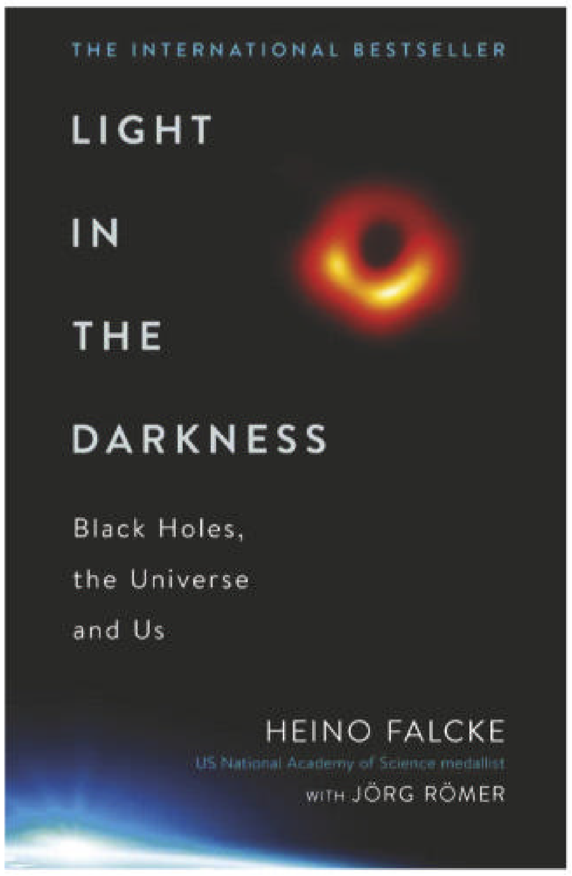
BOOKS



Light in the Darkness

Heino Falcke
Wildfire
£20 ● HB

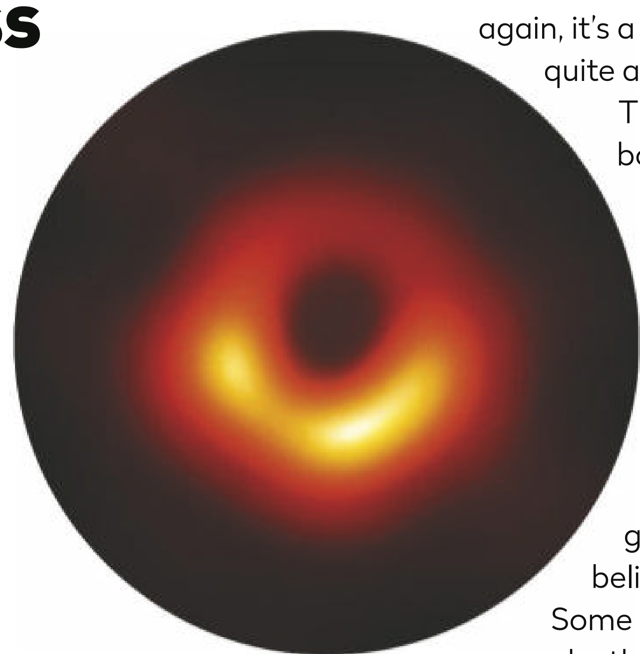
Two years ago, an iconic photo graced the front pages of newspapers all over the world: a slightly asymmetric orange ring, surrounding a pitch-black centre.

The first image of a black hole, some 55 million lightyears away, put us face to face with the ultimate cosmic mystery: a one-way abyss in spacetime that may hold the key to our deepest understanding of nature.

The black hole image was the result of years of planning, organising and fundraising. Radio observatories across the world (including ALMA) joined forces, and telescopes needed high-tech upgrades. Personal rivalry played a role, too, in particular between Harvard astrophysicist Shep Doeleman and Radboud University radio astronomer Heino Falcke – the first director and the science council chair of the Event Horizon Telescope, respectively.

Falcke's book (written with science journalist Jörg Römer) tells the inside story of how astronomers succeeded in linking millimetre-wave telescopes into a virtual 'eye' as large as the planet – the Event Horizon Telescope. By the time the famous image finally was presented to the world, on 10 April 2019, the excitement of the team was palpable. "We have seen the gates of hell at the end of space and time," Falcke said at the press conference.

A large part of *Light in the Darkness* is a pretty basic introduction to the Universe and astronomy in general. This makes the book accessible to a wide audience, but astronomy buffs may have preferred Falcke to delve deeper into black hole physics and the convoluted history of the Event Horizon Telescope instead. Then again, it's a great read, providing quite a lot of detail.



▲ **Every photo tells a story: Heino Falcke recounts the planning behind the iconic image of M87's black hole**

EHT COLLABORATION

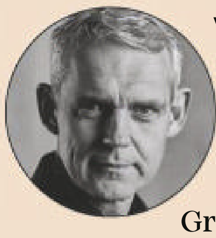
The last part of the book is devoted to Falcke's personal and deeply religious views. He discusses the fundamental limitations of science – with black holes as a prime example – and goes on to express his belief in a personal God. Some readers may wonder why this is relevant in a popular science book.

In 2018, US science writer Seth Fletcher wrote *Einstein's Shadow*, which tells more or less the same story, but from Shep Doeleman's perspective. The two books are very different; but for a complete picture, you should read both.

★★★★☆

***Govert Schilling** is an astronomy writer and author*

Interview with the author
Heino Falcke



What is a black hole?

It's an enormous amount of matter compressed into a tiny amount of space. Gravity and spacetime curvature – Einstein's idea about explaining gravity – becomes so extreme that everything which comes too close cannot escape. It's not a real hole, but a hole in space and time punched into our observable Universe. There is something in this Universe, around this black hole, that we cannot see with our current technology. It's a dark, mysterious region, shielded by an event horizon from which nothing escapes.

How do you photograph a black hole?

We see this dark region in the very centre of the black hole, the darkness of the event horizon, but surrounding it is an enormous amount of light, and that comes from the fact that matter is falling in, heating up, rotating with the speed of light and making a vast amount of radiation and light. Some of the light escapes and we can measure it, and some of it disappears in the darkness. Of course, in our case – with the black hole located in the galaxy M87 – radio light is what we saw.

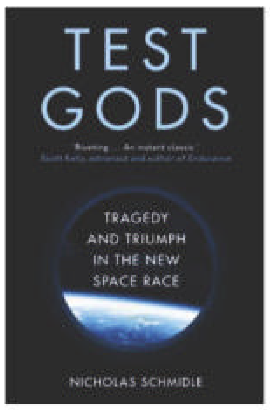
Why did you pick M87's black hole?

To some degree, luck; it seemed that M87 was too small, but over the decades research suggested its mass was bigger and we might have a shot at it. In 2017 we imaged both the centre of the Milky Way and M87, just to see what it would look like. A year later I saw the first data and I just fell off my chair. Actually, I was standing, but I think I was just floating above the ground for about an hour.

***Heino Falcke** is Professor of Radio Astronomy and Astroparticle Physics at Radboud University, Nijmegen, the Netherlands*

Test Gods

Nicholas Schmidle
Hutchinson
£20 ● HB



The Kármán line, 100km above Earth's sea level, is one definition of the boundary between Earth's atmosphere and outer space. Beyond that you are in suborbital space. Test pilot Mike Stucky made Virgin Galactic suborbital in late 2018, when he flew its SpaceShipTwo craft just beyond NASA's definition of Earth's atmosphere (80km above sea level).

This was a company that only four years previously had suffered a tragic blow when a test flight fatally crashed.

The intervening years are the focus of Schmidle's book, a detailed account of the inner workings of Virgin Galactic and the massive effort required to achieve the first step towards space tourism after 15 years of research, testing and millions in investment. The unique appeal of this book is that SpaceShipTwo's progress is told through personal accounts from members of the teams involved, and the cost of their obsession to make the impossible possible.

With test pilot Stucky as the lead character, the book grabs our attention from the start. Capturing the urgency and danger of a test pilot's life, the author uses his access to the company for four years to give a candid account of this emerging sector of space travel.

Yet as much as the author's interest is in understanding Stucky's commitment to his job, it is also to explore his own father's obsession, who was himself a test pilot.

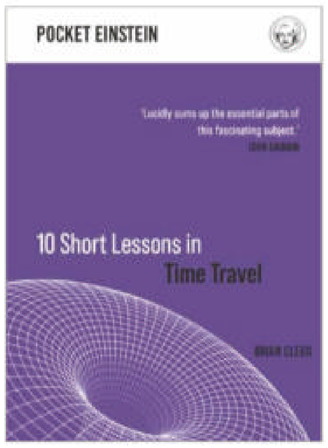
This gripping read is a must for those with even a passing interest in the world of suborbital spaceflight. ★★★★★

***Niamh Shaw** is a science communicator, writer and speaker*

10 Short Lessons in Time Travel

Brian Clegg
Michael O'Mara
£9.99 ● HB

MIND-BLOWING PHYSICS



Time travel is surely one of the most enticing concepts in all of modern science, and any book that opens with a discussion of the 1963 arrival of *Doctor Who* on our screens – a mere day after the assassination of JFK (one of fictional time travel's perennial nexus points) – has already gone a long way towards winning this reviewer over.

Happily, as one of a pair of titles launching the Michael O'Mara publishing house's new Pocket Einstein series, Brian Clegg's guide to the theory and practice of time travel keeps its promise and is a highly enjoyable and informative read.

As its title suggests, the book comprises 10 brief essays on different aspects of the topic. Clegg begins with its fascination for writers and filmmakers, philosophical speculations about the nature of time, and the one-way trips promised by cryogenicists.

He then moves onto the realities of time travel presented by Einstein's theories of special and general relativity, and considers the technical challenges that would have to be overcome in order to take advantage of these apparent loopholes in the laws of physics, before looking at the paradoxes that might ensue.

The journey is seasoned with light-touch references to fictional time travel, from HG Wells and Robert A Heinlein to Robert Zemeckis and Audrey Niffenegger, and intriguing historical asides. It all makes for an engaging primer in a fascinating subject. ★★★★★

***Giles Sparrow** is a science writer and a fellow of the Royal Astronomical Society*

Letters of Note: Space

Shaun Usher (editor)
Canongate
£7.99 ● PB

The best things come in small packages, and this little book is no exception. *Letters of Note: Space* is a Pandora's Box featuring written correspondence, sent from both Earth and space, that reaveals the thoughts of astronauts, cosmonauts, astronomers, engineers, presidents, politicians, parents and children. All the communications are insightful and deeply moving, evoking feelings of hope, awe, rage, remorse, disappointment and fear.

We hear the hopeful voices of African Americans at a time when Black lives appeared not to matter; a girl aspiring to be an astronaut; a would-be astrophysicist who, despite racial challenges, succeeded. We can empathise when a female 'computer' makes a simple plea for an equal wage. We smile at a schoolboy's request for Australia to join the Space Race – his missive backed up with prescient rocket designs. And we chuckle at early ideas about life on Venus and Mars, and identify with a lady's lifelong love of ET. We're enraged at an engineer's unheeded warning that could have prevented the shocking Challenger Space Shuttle disaster, and feel chilled by the pre-prepared presidential statement to be issued should the Apollo 11 astronauts have never made it safely back to Earth. The love of an orbiting astronaut father for his son, his loneliness without his wife, and his longing for Earth's 'elementals' jumps off the page.

These letters are deeply insightful historical markers. Poignant, disturbing, potent, beautiful, thought-provoking, utterly addictive, they offer a timeless connection not just with each other but with the vast cosmos itself. ★★★★★

***Jane Green** is an astronomer, presenter and author of the Haynes Astronomy Manual*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Altair XRings for 60EDF refractors

Price £99.50 • **Supplier** Altair Astro
www.altairastro.com

An easy mounting solution, this quick release ring mechanism clamps around any scope tube with an outer diameter of 75.5mm to 76.5mm, to give you a carry bar on top and a Vixen rail on the bottom.

2 Meteorite slice

Price £75 • **Supplier** Not on the high street
www.notonthehighstreet.com

This is a unique gift that's out of this world – a slice from the Muonionalusta meteorite that crashed to Earth over 110,000 years ago. The display case suspends the slice, showing off the characteristic Widmanstätten pattern found in iron meteorites.

3 Mujjo double insulated touchscreen glove

Price £54.90 • **Supplier** Mujjo • **www.mujjo.com**

Crafted to withstand colder temperatures, these gloves let you continue using your touchscreen devices without taking them off. The palm and fingers have silicone grip lines to make sure you don't fumble an eyepiece or drop a filter while observing.

4 Pale Blue Dots Peppermints

Price £3.95 • **Supplier** Present Indicative
www.presentindicative.com

In 1990, astronomer Carl Sagan organised a family photo of the Solar System taken by Voyager 1, showing Earth as a 'pale blue dot'. To commemorate the image, this tin contains 60 pale blue peppermints, so you can stay fresh while contemplating the Universe.

5 Celestron carry bag for 8-inch telescopes

Price £89.99 • **Supplier** Harrison Telescopes
Tel 01322 403407 • **www.harrisontelescopes.co.uk**

Protect your scope during transport or while storing it with this soft case. An internal strap helps to keep the optical tube securely in place, while an external pocket provides a handy place to keep your eyepieces.

6 ZWO 5V EAF (electronic automatic focus motor)

Price from £184 • **Supplier** Widescreen Centre •
Tel 01353 776199 • **www.widescreen-centre.co.uk**

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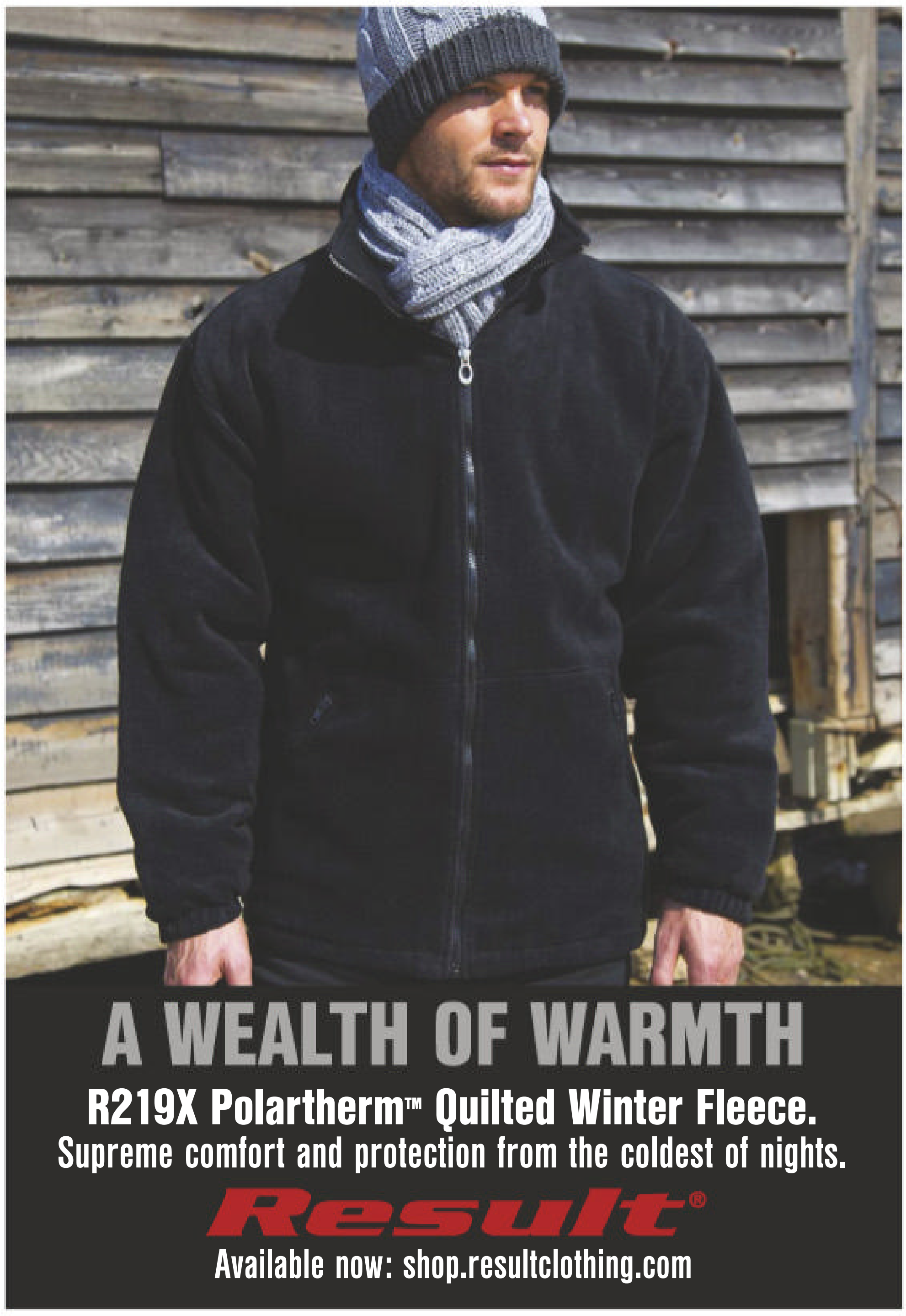
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Ezzy Pearson interviews Professor Chris Mason

Q&A WITH AN ASTRONAUT GENETICIST

Living and working in space takes its toll on the human body, but rewriting our genetic code could help astronauts thrive off-world

What does space travel do to the human body?
Space is rough on the body: the bones start to decay – you can actually see calcium coming out in urine for most astronauts. Some of your veins and arteries can get inflamed, because you have a lot of radiation coming at you and the fluids move around your body in different ways. It's hard on the body but we are extraordinarily adaptive. Even though we see damaged DNA and dying cells, we see regeneration and adaptation. We can see that the body responds quickly to space flight.

▲ **Twins study: during Scott Kelly's tenure on the ISS (for a year from March 2015), scientists compared the effects of space on his body to his Earth-bound identical twin, Mark**

NASA

What is the biggest problem for astronauts?
The number one issue for astronauts is probably radiation. On the International Space Station (ISS), you're still within the protective blocks of Earth's magnetosphere yet you're still getting the equivalent of about five full body X-rays of radiation per day, and that starts to add up. There's also the change in gravity and the isolation. If you have a bad day on Earth, you can take a walk outside, but if something goes wrong in space you can't do that. Part of the isolation is that there's nowhere to go.

What can we do to prevent the damage to the human body?
We already modify human cells therapeutically and use them routinely today for immunotherapy to treat diseases like cancer. Now we're thinking about creating temporary – or possibly permanent – genetic changes to help enable features that we already have in our body. It may seem like science fiction, but it doesn't require any new strange technology or new chromosome that we don't already have in our genome. You could turn on genes just as you need them. For example, if you have a higher burst of radiation, we could increase DNA repair enzymes for just a little while and then bring them back down later. We can learn from evolution to enable us to survive in places that we currently can't.

Professor Chris Mason is a geneticist and author of *The Next 500 Years*, published by The MIT Press

What kinds of things in the body could you switch on?
For example, if you are vitamin C-deficient (from not eating enough limes) you might get scurvy. However, there is a gene for synthesising vitamin C that's in our DNA; it's just been inactivated through evolution. We could make all of our own vitamin C – there are other primates that do this. There are things we've learnt about our genome that we have found and said, "Well, what if we just put that back to the way it used to be?" We wouldn't just deploy biological adaptation mechanisms to survive, we would still need protective suits and hardware and pharmacological interventions; but we're adding another layer

You were part of the Scott Kelly experiment, where he spent a year on the ISS while his identical twin remained on Earth. What did this teach us?
I was the head geneticist for the study. We saw so many things change, everything from his DNA to his vitamin levels. His eyes changed and so did the microbes in his stomach, while the artery in his neck got bigger and he got two inches taller. It was extraordinary, because almost everything went back to normal back on Earth, given a few days. We're expanding the study to future missions, to look at other astronauts and see what happens to the body, to learn how we can make it less stressful or painful.

Why do you think it's important for humans to learn how to live in space?
It's a sense of duty. Humans have a unique duty that no other species have. As far as we know, we're the only species that have this unique awareness of extinction. It's only humans who can understand what it means for a species, or even for all of life, to go away. That means it's only us that can prevent it. Our track record on this is mixed as humanity goes. I think life is very precious and so I'd like it to last longer than just the lifespan of this planet or the Solar System.


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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Catch Comet 7P/Pons-Winnecke and enjoy views of the Northern and Southern Crowns

When to use this chart

1 June at 00:00 AEST (14:00 UT)
15 June at 23:00 AEST (13:00 UT)
31 June at 22:00 AEST (12:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

JUNE HIGHLIGHTS

Comet 7P/Pons-Winnecke reached perihelion in late May and will spend June near maximum brightness at 8th magnitude; it rises in the late evening and is visible for the rest of the night. Opening June in the constellation of Capricornus, the comet passes through Aquarius and Piscis Austrinus, and ends up in Sculptor. Passing between Jupiter and Saturn in the first week, it is 1° from the Helix Nebula on the 15th, while on the 25th it is 1.5° from Fomalhaut (Alpha (α) Piscis Austrini).

STARS AND CONSTELLATIONS

Here's a tale of two celestial crowns. The semicircle of faint stars between Boötes and Hercules is the constellation of Corona Borealis, the Northern Crown. Mythology depicts a jewel-encrusted gold crown worn by Princess Ariadne of Crete when she married the god Dionysus. The alpha star (Alpha (α) Coronae Borealis) is known as Gemma, Latin for jewel. To the south lies Corona Australis, the Southern Crown, a similar semicircle of stars below the Teapot asterism of Sagittarius.

THE PLANETS

The early northwest evening sky is home to Venus with Mars above. The planets gradually draw closer together during June. Saturn and Jupiter are the next targets, standing out in a barren part of the heavens low in the east in the late evening (rising about 21:00 and 22:30 midmonth, respectively). The ice giant planets are morning objects with Neptune appearing in the early hours and Uranus in the predawn. In June's latter half, Mercury returns to the dawn sky.

DEEP-SKY OBJECTS

This month we visit the far northern constellation of Canis Venatici (as viewed from mid-latitude Australia). The Whale Galaxy, NGC 4631 (RA 12h 42.1m, dec. +32° 33') is an edge-on spiral (mag. +9.0), appearing as a bright streak (12' x 1'). Closer inspection reveals a mottled surface with some bright knots along its equator. Its western end tapers to a point with its central bulge offset slightly towards its more blunt eastern extreme.

Another fainter streak, NGC 4656 (also an edge-on spiral), is visible in the same low power field (0.5° SE) – what a bonus!

The (mag. +6.2) globular cluster, M3 (RA 13h 4642.2m, dec. +28° 23') has a bright core (4' across), which gradually brightens towards the centre. The intensity of the surrounding halo drops off sharply beyond the core. Many stars are resolved across the entire globular.

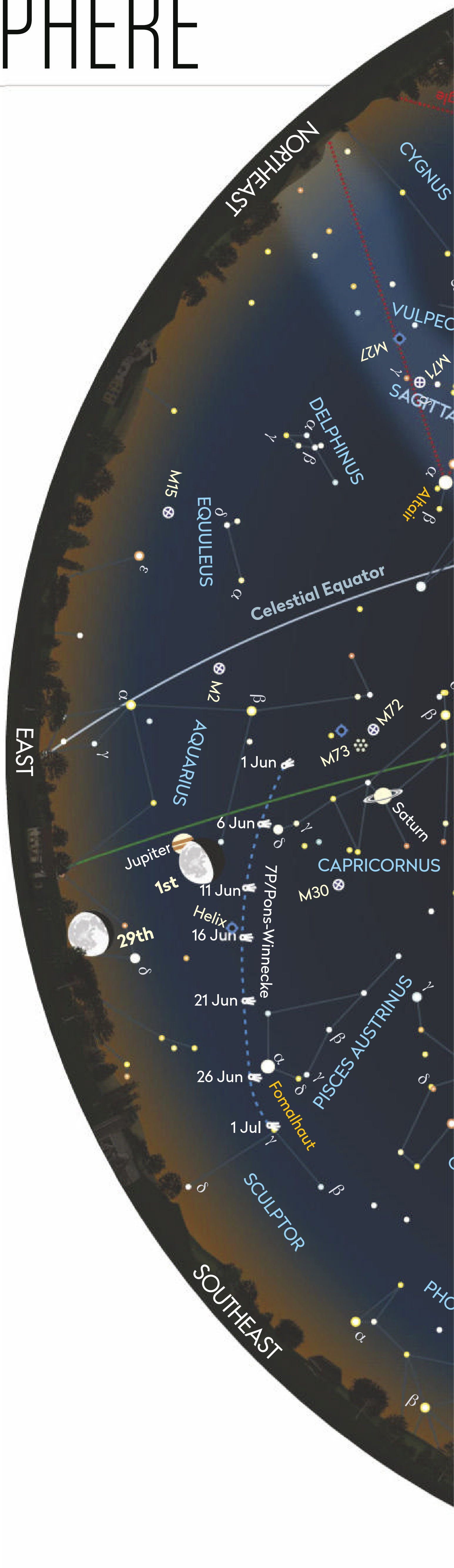

Chart key

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET
STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
HERCULES
M92
M13
Keystone
Vega
LYRA
M57
Summer Triangle
Albireo
BOÖTES
Kite
CORONA BOREALIS
Arcturus
COMA BERENICES
NGC 4631
M3
M53
Rasalgethi
OPHIUCHUS
Rasalhague
Coffin
SERPENS CAPUT
SERPENS CAUDA
AQUILA
M5
M10
M12
M14
M107
M9
VIRGO
Realm of Galaxies
M100
M60
M58
M87
M86
M61
LEO
17th
20th
23rd
26th
Ecliptic
Spica
M104
LIBRA
SCUTUM
M11
M16
M17
M18
M23
M20
M8
M6
M7
M4
Antares
Barnard 228
Teapot
SAGITTARIUS
SCORPIUS
Fish Hook
CORVUS
CRATER
M83
M68
Omega Centauri
NGC 4945
LUPUS
NORMA
ARA
CORONA AUSTRALIS
TELESCOPIUM
Rigel Kent
Hadar
CIRCINUS
CENTAURUS
HYDRA
Peacock Star
INDUS
PAVO
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ASTRONOMY NOW MAGAZINE REVIEW BY NIK SZYMANEK

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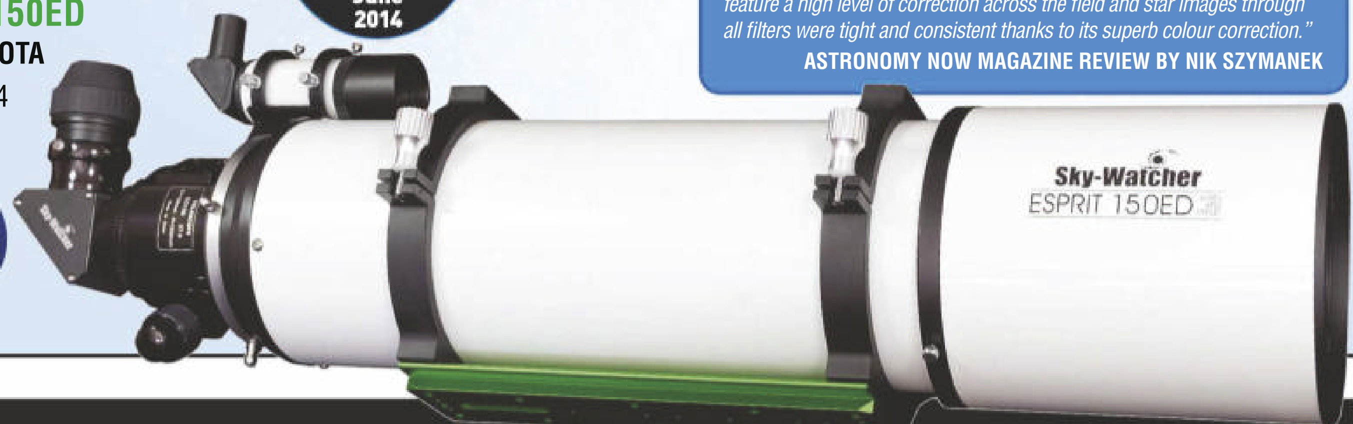

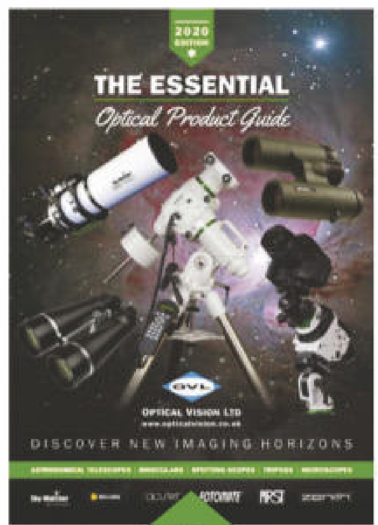

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